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WEATHER BUREAU

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MONTHLY WEATHER REVIEW

VOLUME 44, No. 11

NOVEMBER, 1916

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the Editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

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INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office. Occasional original papers by prominent students of seismological phenomena.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service, monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDUM.

Chart VIII of the October, 1916, issue was *canceled* by "the appropriate official" without advising the Editor, consequently it does not appear among the charts at the back of that issue, although it has a serial number in the Table of Contents.—C. A., jr.

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING NOVEMBER, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Dec. 28, 1916.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, April, and May, 1916, **44**:2, 179–180 and 244, respectively.

The monthly means and departures from normal values given in Table 1 show that direct solar radiation intensities averaged slightly below normal at Washington, D. C., and Lincoln, Nebr., and slightly above normal at Madison, Wis., and Santa Fe, N. Mex. At Lincoln, Nebr., a noon intensity of 1.56 calories on the 24th exceeds any noon intensity measured at that station during November, 1915.

Skylight polarization measurements made at Washington on 13 days, with the sun at zenith distance 60°, give a mean of 54 per cent and a maximum of 64 per cent on the 27th. This latter is 8 per cent less than the maximum obtained in November, 1914; but it is 6 per cent greater than the November maxima of 1903 and 1904. The monthly mean is 9 per cent less than the November mean for the two years 1914 and 1915.

TABLE 1.—*Solar radiation intensities during November, 1916.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
		Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
A. M.										
Nov. 1	.....	1.36	1.19	1.08	0.94	0.83	0.77	0.71	0.66	0.62
2	.....	1.31	1.19	1.07	1.01	0.92	0.87	0.81	0.75	0.70
3	.....	1.34	1.19	1.13	1.10	0.96	0.83	0.73	0.64	.....
7	.....	.....	1.07	1.00	0.84	0.74	0.66	0.61	0.57	0.54
8	.....	.....	1.05	0.89	0.77	0.68	0.60	0.54	0.48	0.41
11	.....	.....	1.14	1.11	1.01	0.91	0.83	0.77	0.72	0.66
16	.....	.....	1.26	1.13	1.05	0.97	0.90	0.83	0.74	.....
17	.....	.....	1.13	1.08	1.04	.....	.....	.....	.....	.....
18	.....	.....	0.94	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	1.21	.....	.....	.....	.....	.....	.....	.....
20	.....	.....	1.22	1.06	0.94	0.84	0.78	0.73	0.68	0.65
25	.....	.....	1.27	1.16	1.06	0.97	0.91	0.85	0.80	0.75
26	.....	.....	.....	1.04	0.96	0.89	.....	.....	.....	.....
27	.....	.....	1.32	.....	.....	.....	1.02	0.97	0.94	.....
Monthly means	.....	1.34	1.17	1.07	0.97	0.87	0.82	0.76	0.70	0.62
Departure from 9-year normal	.....	−0.07	−0.02	−0.03	−0.05	−0.04	−0.03	−0.03	−0.05	−0.07
P. M.										
Nov. 1	.....	.....	1.25	1.13	1.01	0.92	0.85	0.80	0.74	0.70
2	.....	.....	1.20	1.11	1.00	0.91	0.83	0.76	0.70	0.65
3	.....	.....	1.17	1.02	0.92	0.84	0.74	0.63	0.54	0.47
7	.....	.....	0.90	0.77	0.66	0.57	0.50	0.45	0.40	.....
8	.....	.....	1.16	1.15	1.04	0.94	0.87	0.80	.....	.....
10	.....	.....	1.32	1.21	1.11	1.01	0.92	0.85	0.79	0.74
11	.....	.....	1.01	0.89	0.72	0.62	0.53	0.47	0.42	0.38
16	.....	.....	1.24	1.13	1.03	0.95	0.89	0.85	0.82	.....
17	.....	.....	.....	.....	0.89	0.80	0.72	0.66	0.60	0.56
21	.....	.....	.....	1.16	1.07	0.99	0.91	0.82	0.73	0.66
24	.....	.....	1.28	1.20	1.12	1.05	0.97	0.90	0.87	.....
25	.....	.....	.....	1.14	1.07	1.01	0.94	0.89	0.85	0.80
27	.....	.....	.....	1.16	1.10	1.04	0.98	0.77	0.75	0.70
Monthly means	.....	.....	1.17	1.09	0.98	0.90	0.82	0.74	0.68	0.63
Departure from 9-year normal	.....	.....	−0.03	±0.00	±0.00	±0.00	±0.00	−0.03	−0.04	−0.04

TABLE 1.—*Solar radiation intensities during November, 1916*—Con.

Madison, Wis.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
		Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
A. M.										
Nov. 2	.....	.....	1.33	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	1.20	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	1.28	1.22	1.14	1.09	1.02	0.95	0.92	.....
14	.....	.....	1.37	1.34	1.24	1.18	1.12	1.04	0.96	0.87
15	.....	.....	1.36	1.24	1.15	1.03	0.93	.....	.....	.....
18	.....	.....	1.38	1.24	1.16	1.07	1.00	0.93	.....	.....
25	.....	.....	.....	.....	.....	.....	1.07	.....	.....	.....
29	.....	.....	.....	1.17	.....	.....	.....	.....	.....	.....
30	.....	.....	.....	.....	.....	.....	1.06	0.99	0.93	0.87
Monthly means	.....	.....	1.32	1.24	1.17	1.09	1.03	0.98	0.94	0.87
Departure from 7-year normal	.....	.....	+0.01	+0.03	+0.03	−0.07	±0.00	±0.00	+0.10	+0.10
P. M.										
Nov. 1	.....	.....	1.36	1.27	1.18	.....	.....	.....	.....	.....
4	.....	.....	.....	1.26	1.19	.....	.....	.....	.....	.....
9	.....	.....	1.28	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	1.29	1.24	1.17	.....	.....	.....	.....
15	.....	.....	.....	1.30	1.25	.....	.....	.....	.....	.....
18	.....	.....	.....	.....	1.16	1.07	.....	.....	.....	.....
29	.....	.....	.....	1.23	1.20	1.12	.....	.....	.....	.....
Monthly means	.....	.....	1.32	1.27	1.20	1.12	.....	.....	.....	.....
Departure from 7-year normal	.....	.....	.....	+0.01	+0.02	+0.10	.....	.....	.....	.....

Lincoln, Nebr.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
		Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
A. M.										
Nov. 1	.....	.....	1.40	1.32	1.27	1.15	1.05	1.03	.....	.....
4	.....	.....	1.22	1.20	1.08	0.98	0.88	0.82	0.78	.....
6	.....	.....	1.38	1.13	1.07	0.98	0.91	0.85	0.81	.....
13	.....	.....	1.48	1.37	1.27	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	1.14	1.10	1.06	.....
15	.....	.....	.....	1.44	1.37	1.30	1.23	1.17	1.11	.....
16	.....	.....	.....	.....	1.24	1.21	1.15	1.07	1.00	0.93
17	.....	.....	.....	.....	1.33	.....	.....	.....	1.04	1.02
24	.....	.....	.....	1.49	1.39	1.33	1.26	1.21	1.17	1.13
25	.....	.....	1.38	.....	1.24	1.15	1.06	0.98	0.90	.....
29	.....	.....	1.45	1.39	1.33	1.26	1.17	1.13	1.07	1.00
Monthly means	.....	.....	1.38	1.33	1.26	1.17	1.09	1.04	0.99	1.02
Departure from 2-year normal	.....	.....	−0.02	−0.04	−0.02	−0.02	−0.02	−0.02	−0.01	.....
P. M.										
Nov. 1	.....	.....	1.35	1.26	.....	.....	.....	.....	.....	.....
2	.....	.....	1.42	1.33	1.23	1.11	1.05	0.98	0.90	.....
4	.....	.....	1.22	1.14	1.01	0.92	0.85	0.79	0.72	.....
6	.....	.....	1.38	1.29	1.18	1.10	1.02	0.94	0.85	.....
13	.....	.....	1.48	1.44	1.34	1.27	1.20	1.14	1.08	1.04
14	.....	.....	.....	1.38	1.31	1.24	1.17	1.11	1.06	.....
17	.....	.....	1.51	1.40	1.32	1.25	1.17	1.12	1.07	.....
24	.....	.....	1.57	1.48	1.38	1.24	1.16	1.09	1.01	0.93
25	.....	.....	.....	1.41	.....	.....	.....	.....	.....	.....
28	.....	.....	1.37	.....	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	1.39	1.27	1.22	1.15	1.07	1.02	0.98
Monthly means	.....	.....	1.41	1.35	1.26	1.17	1.10	1.03	0.96	0.98
Departure from 2-year normal	.....	.....	−0.02	±0.00	+0.01	±0.00	±0.00	−0.01	−0.02	−0.02

TABLE 1.—*Solar radiation intensities during November, 1916*—Con.

Santa Fe, N. Mex.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.		Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Nov. 1	.....	1.56	1.50	1.45	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	1.13	1.08	.....	.....
10	.....	1.55	1.53	1.47	1.39	1.32	1.29	1.27	1.22	.....
11	.....	.....	1.52	.....	.....	1.37	.....	.....	1.22	.....
14	.....	1.63	1.58	1.52	1.44	.....	.....	.....	.....	.....
15	.....	1.60	1.55	1.48	1.41	.....	.....	.....	.....	.....
17	.....	.....	1.42	1.38	1.31	1.22	.....	.....	.....	.....
25	.....	.....	1.54	1.47	.....	.....	.....	1.18	1.17	.....
28	.....	.....	1.50	.....	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	1.46	1.38	1.31	1.21	1.07	.....	.....
Monthly means	.....	1.58	1.52	1.46	1.39	1.30	1.21	1.15	1.20	.....
Departure from 5-year normal	.....	+0.01	+0.04	±0.00	+0.03	+0.02	±0.00	±0.00	±0.00	.....
P. M.										
Nov. 1	.....	.....	1.48	1.38	1.30	1.26	.....	.....	.....	.....
10	.....	.....	1.50	1.43	1.36	1.32	1.27	1.21	.....	.....
14	.....	.....	.....	.....	1.26	1.17	.....	.....	.....	.....
15	.....	.....	.....	1.48	1.41	1.36	1.29	1.22	.....	.....
23	.....	.....	.....	1.48	1.43	1.32	.....	.....	.....	.....
28	.....	.....	1.50	1.41	1.34	1.21	1.14	1.08	.....	.....
29	.....	.....	.....	.....	1.35	1.28	.....	.....	.....	.....
Monthly means	.....	.....	1.49	1.44	1.35	1.27	1.23	1.17	.....	.....

TABLE 2.—*Vapor pressure at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1916.	Mm.	Mm.	1916.	Mm.	Mm.	1916.	Mm.	Mm.	1916.	Mm.	Mm.
Nov. 1	5.16	3.30	Nov. 1	3.81	3.99	Nov. 1	3.63	4.57	Nov. 1	3.45	3.63
2	4.95	5.36	2	3.99	3.81	2	3.99	4.37	6	2.36	3.15
3	4.57	4.95	4	6.50	4.75	4	5.79	6.76	10	2.87	3.00
7	7.04	6.76	9	4.37	4.37	6	9.14	3.00	11	2.36	2.74
8	6.50	7.04	14	1.12	1.24	13	1.37	1.12	14	1.19	1.68
10	5.16	5.56	15	1.45	1.24	14	0.79	1.37	15	1.32	1.88
11	5.79	4.75	18	2.49	4.37	15	1.32	2.26	17	1.45	2.06
16	1.78	2.36	25	1.60	2.62	16	3.30	3.45	23	2.62	2.26
17	2.74	3.99	29	5.36	3.00	17	3.30	3.15	25	2.06	3.63
18	3.99	3.81	30	2.87	3.45	24	1.96	1.88	28	2.06	2.06
19	3.00	4.17	.....	.....	.....	25	2.62	3.99	29	1.68	1.88
20	4.57	5.56	.....	.....	.....	28	3.15	4.17	.....	.....	.....
21	3.00	3.63	.....	.....	.....	29	3.15	3.63	.....	.....	.....
24	5.16	2.06	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	1.60	1.96	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	1.88	2.62	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	3.30	3.63	.....	.....	.....	.....	.....	.....	.....	.....	.....

Table 3 shows about the normal amount of radiation for the month at Madison and deficiencies of 4 per cent and 5.5 per cent at Lincoln and Washington, respectively.

But few half-day series of direct solar radiation measurements at any of the stations indicate even approximately steady sky conditions. At Santa Fe this is principally due to the effect of city smoke. The best series obtained have been extrapolated to zero air mass; and from the values of Q_0 thus obtained, in connection with the vapor pressures of Table 2, the value of the solar constant has been computed by the Smithsonian abridged method. The results for the different stations, as shown by Table 4, are in good accord with each other and also with Abbot's mean value. Previous experience would lead us to expect this result during the cold part of the year, when the surface vapor pressure does not differ greatly from station to station.

TABLE 3.—*Daily totals and departures of solar and sky radiation during November, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals. Washington.	Madison.	Lincoln.	Departures from normal. Washington.	Madison.	Lincoln.	Excess or deficiency since first of month. Washington.	Madison.	Lincoln.
	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Nov. 1	347	287	315	87	86	49	87	86	49
2	314	290	294	57	92	31	144	178	80
3	328	120	245	74	− 75	− 15	218	103	65
4	110	280	297	−141	88	40	77	191	105
5	254	219	277	6	30	23	83	221	128
6	125	222	305	−121	35	53	− 38	256	181
7	298	59	92	55	−125	−157	17	131	24
8	291	15	119	51	−166	−127	68	− 35	−103
9	288	265	246	50	87	3	118	52	−100
10	287	143	152	52	− 33	− 88	170	19	−188
11	263	73	60	31	−100	−178	201	− 81	−366
12	55	12	63	−174	−158	−172	27	−239	−538
13	81	85	330	−146	− 82	98	− 119	−321	−440
14	67	283	311	−157	119	82	− 276	−202	−358
15	73	279	285	−148	118	59	− 424	− 84	−299
16	303	193	233	84	34	9	− 340	− 50	−290
17	274	159	280	58	2	59	− 282	− 48	−231
18	219	249	250	6	95	31	− 276	47	−200
19	269	234	259	58	82	43	− 218	129	−157
20	226	87	244	18	− 63	30	− 200	66	−127
Decade departure							− 370	47	61
21	228	70	33	22	− 78	−178	− 178	− 12	−305
22	161	41	49	− 42	−105	−160	− 220	−117	−465
23	34	64	152	−166	− 80	− 55	− 386	−197	−520
24	242	160	272	44	18	68	− 342	−179	−452
25	253	190	235	58	50	33	− 284	−129	−419
26	240	173	239	47	34	39	− 237	− 95	−380
27	263	52	208	72	− 86	10	− 165	−181	−370
28	159	129	206	− 30	− 8	10	− 195	−189	−360
29	56	184	256	−131	48	62	− 326	−141	−298
30	146	214	223	− 39	79	31	− 365	− 62	−267
Decade departure							− 165	−128	−140
Excess or deficiency since first of year: Gr.-cal.							−5,896	+3,224	.....
Excess or deficiency since first of year: Per cent							−4.7	+2.7	.....

TABLE 4.—*Solar radiation intensities for zenithal sun, reduced to mean solar distance of the earth, and approximate values of the solar constant.*

[Gram-calories per minute per square centimeter of normal surface.]

Station.	Date.	Radiation intensity. $m=1$.	Radiation intensity. $m=0$.	Solar constant.
	1916.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Lincoln, Nebr.	Nov. 6, p. m.	1.61	1.83	1.94
	Nov. 13, p. m.	1.64	1.83	1.90
	Nov. 15, a. m.	1.65	1.82	1.89
	Nov. 24, a. m. and p. m.	1.70	1.89	1.98
	Nov. 29, a. m.	1.60	1.78	1.89
Mean				1.92
Washington, D. C.	Nov. 1, p. m.	1.52	1.83	1.94
Santa Fe, N. Mex.	Nov. 15, p. m.	1.67	1.84	1.92

THE DURATION AND INTENSITY OF TWILIGHT.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Nov. 25, 1916.]

INTRODUCTION.

Officials of the Weather Bureau frequently receive requests for information relative to the intensity of the light at some specified time, usually during the hours of twilight. Twilight illumination is, of course, markedly influenced by the state of the sky as regards clouds, haze, smoke, etc. Aside from this it is dependent on the angular depression of the sun below the horizon and the position and phase of the moon.

THE DURATION OF TWILIGHT.

One of the earliest accessible treatises on twilight is by Johann Heinrich Lambert,[1] who states that ancient astronomers had found for the beginning of complete darkness at night and its ending in the morning a depression of the sun below the horizon of from 18° to 19°.[2] According to Kaemtz [3] they also gave as a rule that at this time stars of the sixth magnitude should be visible near the zenith.

Kaemtz [4] also describes the anti-twilight, which includes what many observers have called the anticrepuscular or anti-twilight arch, below which the sky is of an ashy or a deep blue color, depending on its clearness, and above which it takes on a reddish tinge. Under favorable atmospheric conditions, and specially in arid regions at a considerable elevation above sea level, this arch may be observed to rise in the east soon after sunset. Lambert,[5] at Augsburg, Germany, on November 19, 1759, made measurements from which he computed that it passed his zenith when the sun was 5° 50′ lower than at its apparent setting; or, allowing 33′ for atmospheric refraction, when the depression of the sun below the horizon was 6° 23′. Bravais,[6] from observations made on the summit of the Faulhorn, Switzerland, at an elevation of 2,685 meters above sealevel, found it to pass his zenith when the sun was 6° 9′ below the horizon, and to reach the horizon when the depression of the sun was 17° 30′.

On the assumption that the anti-twilight arch represents the limit of direct illumination of the atmosphere by the sun, Lambert [7] shows that a depression of the sun below the horizon of 18° 30′ at the end of twilight gives 1/89th part of the earth's radius, or about 70 kilometers, as the height to which the atmosphere is capable of reflecting sunlight. This seemed to him to be too high, and he therefore supposed twilight to be divided into two periods, a primary twilight, and a secondary twilight. The primary twilight he attributed to light reflected from portions of the atmosphere directly illuminated by the sun. Secondary twilight he attributed to reflection of light from portions of the atmosphere illuminated by the primary twilight.

Assuming that the end of this secondary twilight corresponds to the beginning of complete darkness, and, therefore, to a depression of the sun below the horizon of 18° 30′, Lambert [8] computed the height to which the atmosphere is capable of reflecting sunlight to be 1/372d part of the earth's radius, or about 17 kilometers. From his own measurements of the height of the anti-twilight arch with the sun 8° 3′ below the horizon, Lambert [9] computed the height to which the atmosphere reflects sunlight to be 1/220th part of the earth's radius, or about 29 kilometers, which is much less than the height now generally accepted. [10] His computation also placed the anti-twilight arch at about the center of the segment of the sky which he supposed to be illuminated by secondary reflection, and he therefore concluded that the light in one half this segment is so feeble as to be obscured by the light of the fixed stars.

This conclusion of Lambert's found favor with Biot,[11] but was rejected by Grunert,[12] who shows that Lambert's observations give increasingly higher values for the height of the upper limit of the reflecting atmosphere with increasing depression of the sun below the horizon.

Kaemtz [13] also states that "This segment [the deep blue of the anti-twilight] is due to the shadow of the earth projected on the sky," and a note by Martins [14] defines the *second twilight* to be the feeble white light that under favorable conditions is sometimes observed from high mountains after the anti-twilight arch has set, and which has been observed to continue until the sun was 26° below the horizon. It is also stated that this second twilight has not been observed at low-level stations.

Láska [15] and also Exner [16] ignore the secondary twilight of Lambert. Following Bezold,[17] however, Exner distinguishes between a "first" and a "second" twilight, the "first" twilight terminating in the evening with the disappearance of the first purple light, which is often a prominent feature of twilight phenomena. According to Bezold's observations, the anti-twilight arch can not be observed to pass the zenith, but can sometimes be seen to reappear in the western sky about 30° past the zenith. Its final disappearance marks the end of astronomical twilight.

Tables of the duration of astronomical twilight.

In early numbers of the Berliner Astronomisches Jahrbuch [18] will be found tables giving the duration of astronomical twilight for each day in the year. From the explanation of the use of the Ephemeriden in the Jahrbuch for 1776, pages 20–21, it appears that sunrise or sunset is considered to be that instant when the center of the sun coincides with the true horizon, disregarding the effect of atmospheric refraction; and that astronomical twilight begins in the morning and ends in the evening when the true position of the sun's center is 18° below the horizon. The interval between the time of sunrise or sunset thus computed and the time the sun is 18° below the horizon is the duration of astronomical twilight given.

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[1] *Lambert's* Photometrie (1760), Zweites Heft: Theil III, IV, and V, pp. 96–112. (Ostwald's Klassiker der exakten Wissenschaften. Nr. 32. Leipzig, 1892.)

[2] For a bibliography summarizing these determinations see *Houzeau, J. C.* Vademecum de l'astronome. Bruxelles, 1882. p. 313–316.

[3] Meteorology, by *L. F. Kaemtz*. Notes by Ch. Martins. Translated by C. V. Walker, London, 1845, p. 410.

[4] Op. cit., p. 408.

[5] Op. cit., p. 101.

[6] *Bravais, M. A.* Observations sur les phénomènes crépusculaires. Annuaire Météorologique de la France pour 1850, 2me Année. p. 185–218. (See Note additionnelle, p. 215.)

[7] Op. cit., p. 102.

[8] *Lambert*, op. cit., p. 102.

[9] Op. cit., p. 106.

[10] See *Heim, Albert*, Luft-Farben. Hofer & Co. Zurich, 1912. p. 68.

[11] *Biot, J. B.* Traité élémentaire d' Astronomie physique. 3d ed. Paris, 1841. Vol. 1, p. 309–323.

[12] *Grunert, Johann August.* Beiträge zur meteorologischen Optik. Leipzig, 1848. Erster Theil, Erstes Heft, p. 194–264.

[13] Op cit., p. 408.

[14] *Kaemtz*, op. cit., p. 409; see also p. 499, note "G."

[15] *Láska, Prof. Dr. W.* Lehrbuch der Astronomie und der mathematischen Geographie. II. Auflage. I. Teil: Sphärische Astronomie. Bremerhaven und Leipzig, 1906, p. 74–78. (Kleyers Encyklopädie der gesamten mathematischen, technischen und exakten Naturwissenschaften.)

[16] *Pernter, J. M., & Exner, Felix M.* Meteorologische Optik. Wien und Leipzig, 1910. p. 739–799.

[17] See Abbe's translation of *Bezold's* description of twilight phenomena, with Exner's discussion, p. 620–623, of this number of the REVIEW.

[18] See the "Ephemeriden" in the Jahrbücher for 1776–1829.

In the Annuaire Astronomique de l'Observatoire Royal de Belgique [19] is published a table giving the duration of astronomical twilight for each fifth degree of latitude at the time of the equinoxes and of the summer and winter solstices that is in accord with the above.

In the Comptes Rendus for 1860, **50**:81, M. F. Petit presents, for latitudes 48° and 49° N., some preliminary computations of the duration of twilight, or the interval between the time the center of the sun appears to be on the horizon, allowing 33′ 30″ for atmospheric refraction, and the time the true position of the sun's center is 18° below the horizon. In the Comptes Rendus for 1860, **51**:486–489, he published a table giving the duration of twilight for each degree of solar declination from −24° to +24° and for each degree of longitude from 0° to 70°.

This table appears to be the basis for most of the tables giving the duration of astronomical twilight since published. Thus, in the "Annuaire Astronomique et Météorologique pour 1893 par Camille Flammarion" is a table giving the duration of astronomical twilight for each fifth degree of latitude and for 15-day intervals, beginning with January 1. No authority is given, but it appears to be in accord with Petit's table, and might, indeed, have been obtained by interpolation in it for the solar declination on the days for which data is given.

Likewise, Láska [20] published a table giving the duration of astronomical twilight that is attributed to the Annuaire for 1905. His table states in the heading that the data refer to the first day of the respective months; but they seem to have been copied directly from the Annuaire, taking for the first day of the respective months the data for the date given in the table that falls nearest the first, although in some cases this may have been as early as the 26th of the preceding month. In a few cases only does it appear that an attempt has been made to obtain correct data by interpolation. This table of Láska's has been copied by Exner.[21]

From the above brief review of the literature it is apparent that the uniform practice in the computation of tables of the duration of astronomical twilight has been to regard the time of its beginning in the morning, or its ending in the evening, as that instant when the true position of the center of the sun is 18° below the horizon; although the earlier observers, as has already been shown, gave a slightly greater depression of the sun at the beginning or end of complete darkness, and later observers have generally found a somewhat less depression, namely, from 16° to 18°. [22] The tables of duration of twilight, however, show variations due to differences with respect to the position of the sun at its rising and setting. The older German writers, as already shown, considered the sun to rise or set when its center coincided with the true horizon, disregarding atmospheric refraction; modern French and Belgians consider sunrise or sunset to be that instant when the *center* of the sun *appears* to be on the true horizon; while modern English and German writers consider it to be the instant when the *upper limb* of the sun appears to be on the horizon. These two latter, therefore, apply a correction for atmospheric refraction to the computed position of the sun at sunrise or sunset.

Table 1 of the present paper gives the length of the period between the time when the upper limb of the sun appears to coincide with the true horizon and the time the true position of its center is 18° below the horizon. Allowing 16′ for the sun's semidiameter, and 34′ for atmospheric refraction, the sun is then only 17° 10′ lower than at the time of sunrise or sunset.

The computations may be made from the equation

$$h = \frac{\sin a - \sin \phi \sin \delta}{\cos \phi \cos \delta}$$

where h is the sun's hour angle from the meridian, a is the sun's altitude, considered minus below the horizon, δ is the solar declination, and ϕ is the latitude of the place of observation.

TABLE 1.—*Duration of astronomical twilight.* (*Interval between sunrise or sunset and the time when the true position of the sun's center is 18° below the horizon.*)

Date.		North Latitude.																			
		0°	10°	20°	25°	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°					
		h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m	h. m					
Jan.	1	1 14	1 15	1 18	1 21	1 26	1 28	1 29	1 31	1 34	1 37	1 41	1 45	1 49	1 53	1 59					
	11	1 14	1 14	1 18	1 21	1 25	1 27	1 29	1 31	1 33	1 36	1 39	1 43	1 47	1 52	1 57					
	21	1 13	1 13	1 17	1 20	1 23	1 25	1 28	1 30	1 32	1 34	1 38	1 41	1 45	1 49	1 54					
Feb.	1	1 12	1 12	1 15	1 18	1 22	1 24	1 26	1 28	1 30	1 33	1 36	1 39	1 43	1 47	1 52					
	11	1 11	1 12	1 14	1 17	1 21	1 23	1 25	1 27	1 29	1 32	1 34	1 37	1 41	1 45	1 49					
	21	1 10	1 11	1 13	1 16	1 20	1 22	1 24	1 26	1 28	1 31	1 33	1 36	1 40	1 44	1 48					
Mar.	1	1 10	1 11	1 13	1 16	1 20	1 21	1 23	1 25	1 28	1 30	1 33	1 36	1 39	1 43	1 48					
	11	1 09	1 10	1 13	1 16	1 19	1 21	1 23	1 25	1 28	1 30	1 33	1 36	1 39	1 43	1 48					
	21	1 09	1 10	1 13	1 16	1 20	1 22	1 24	1 26	1 29	1 31	1 34	1 37	1 41	1 45	1 50					
Apr.	1	1 09	1 11	1 14	1 17	1 21	1 23	1 25	1 27	1 30	1 33	1 36	1 40	1 44	1 49	1 54					
	11	1 10	1 11	1 15	1 18	1 22	1 24	1 27	1 30	1 33	1 36	1 39	1 43	1 48	1 54	2 00					
	21	1 11	1 12	1 16	1 20	1 24	1 27	1 29	1 32	1 36	1 39	1 43	1 48	1 54	2 01	2 08					
May	1	1 12	1 13	1 18	1 22	1 27	1 30	1 33	1 36	1 39	1 43	1 48	1 54	2 01	2 10	2 20					
	11	1 13	1 14	1 19	1 24	1 30	1 33	1 36	1 40	1 43	1 48	1 54	2 01	2 10	2 20	2 35					
	21	1 13	1 15	1 21	1 26	1 32	1 36	1 39	1 43	1 48	1 54	2 01	2 10	2 20	2 35	2 58					
June	1	1 14	1 16	1 23	1 28	1 35	1 38	1 41	1 46	1 52	1 59	2 07	2 18	2 31	2 54	....					
	11	1 15	1 17	1 24	1 29	1 36	1 40	1 44	1 49	1 55	2 02	2 12	2 23	2 40	3 11	....					
	21	1 15	1 18	1 24	1 29	1 37	1 41	1 45	1 50	1 56	2 03	2 13	2 25	2 44	3 19	....					
July	1	1 15	1 17	1 24	1 29	1 36	1 40	1 44	1 49	1 55	2 02	2 12	2 23	2 40	3 10	....					
	11	1 14	1 16	1 23	1 28	1 35	1 38	1 41	1 46	1 52	1 59	2 07	2 18	2 31	2 54	....					
	21	1 13	1 15	1 21	1 26	1 32	1 36	1 39	1 43	1 48	1 54	2 01	2 10	2 21	2 36	3 00					
Aug.	1	1 13	1 14	1 19	1 24	1 30	1 33	1 36	1 40	1 44	1 48	1 54	2 02	2 10	2 20	2 35					
	11	1 12	1 13	1 18	1 22	1 27	1 30	1 33	1 36	1 39	1 43	1 48	1 54	2 01	2 10	2 20					
	21	1 11	1 12	1 16	1 20	1 24	1 27	1 30	1 33	1 36	1 39	1 43	1 48	1 54	2 01	2 09					
Sept.	1	1 10	1 11	1 14	1 18	1 22	1 24	1 27	1 30	1 33	1 36	1 39	1 43	1 48	1 53	2 00					
	11	1 09	1 11	1 13	1 17	1 21	1 23	1 25	1 27	1 30	1 33	1 36	1 39	1 44	1 49	1 54					
	21	1 09	1 10	1 13	1 16	1 20	1 22	1 24	1 26	1 29	1 31	1 34	1 37	1 41	1 45	1 50					
Oct.	1	1 09	1 10	1 13	1 16	1 19	1 21	1 23	1 25	1 28	1 30	1 33	1 36	1 39	1 43	1 48					
	11	1 10	1 11	1 13	1 16	1 19	1 21	1 23	1 25	1 28	1 30	1 33	1 36	1 39	1 43	1 48					
	21	1 10	1 11	1 13	1 16	1 20	1 22	1 24	1 26	1 28	1 31	1 33	1 36	1 40	1 44	1 48					
Nov.	1	1 11	1 12	1 14	1 17	1 21	1 23	1 25	1 27	1 29	1 32	1 34	1 38	1 41	1 46	1 49					
	11	1 12	1 12	1 16	1 18	1 22	1 24	1 26	1 28	1 30	1 33	1 36	1 40	1 43	1 47	1 52					
	21	1 13	1 13	1 17	1 20	1 24	1 26	1 28	1 30	1 32	1 35	1 38	1 42	1 46	1 49	1 55					
Dec.	1	1 14	1 14	1 18	1 21	1 25	1 27	1 29	1 31	1 33	1 36	1 40	1 44	1 47	1 52	1 57					
	11	1 14	1 15	1 18	1 22	1 26	1 28	1 30	1 32	1 34	1 37	1 41	1 45	1 49	1 53	1 59					
	21	1 15	1 16	1 19	1 22	1 26	1 28	1 30	1 32	1 35	1 38	1 41	1 45	1 49	1 54	1 59					

The solar declinations employed are those given in the American Ephemeris and Nautical Almanac, 1899, pp. 377–384, Solar Ephemeris for Washington, which Prof. Marvin has found to be very close average values.[23]

The computations have been simplified by the use of Ball's Altitude Tables,[24] from which the value of h has been determined for true altitudes of the sun of −50′ and −18°. The difference between these two values is the duration of astronomical twilight. It is, therefore, from 1 to 2 minutes less than that given in Petit's table and from 3 to 7 minutes less than that given in the

[19] See, for example, the Annuaire for 1907, p. 193.
[20] Op. cit., p. 77.
[21] *Pernter & Exner*, op. cit., p. 743.
[22] See *Láska*, op. cit., p. 74; *Grunert*, op. cit., p. 221; *Pernter & Exner*, op. cit., p. 743, 766, 767; *Schmidt, J. F. Julius*. Ueber die Dämmerung. Astronomische Nachrichten No. 1495-1496, Altona, 1865, **36**, col. 97–116.

[23] *Marvin, C. F.* Sunshine Tables. Edition of 1905, p. 3. (W. B. No. 320.)
[24] *Ball, Frederick*. Altitude Tables for lat. 31° to 60°. London, 1907; [same] for lat. 0° to 30°, London, 1910.

Berliner Astronomisches Jahrbuch and in the Annuaire Astronomique de Belgique above quoted, the magnitude of the differences increasing with the latitude.

Tables of the duration of civil twilight.

Definitions of civil twilight.—There is a lack of definiteness and of uniformity in the definitions of *civil twilight*. Thus the Berliner Astronomisches Jahrbuch for 1776, in the explanation of the use of the Ephemeriden, page 22, gives what it calls Lambert's definition of the beginning of civil twilight in the morning or its ending in the evening, namely, when the center of the sun is 6° 23½′ below the horizon,[25] or 5° 50′ lower than when its center appears to coincide with the true horizon, at which time the [anti-] twilight arch passes through the zenith. Also, Bravais [26] states that "The results obtained show that the passage of the [anti-twilight] curve at the zenith, the commencement or end of the civil twilight of Lambert, occurs when the sun reaches a zenith distance of 96°." Abbe, sr.,[27] gives a similar definition, except that he does not give the position of the sun. Kaemtz [28] distinguishes astronomical from ordinary twilight, the latter terminating "when darkness compels us to suspend labour that is going on in the open air." Láska's definition is similar, except that he adds that the sun is then about 6½° below the horizon. Bezold [29] identifies the end of civil twilight with the disappearance of the first purple light, when the sun is about 6° below the horizon. This is also Gruner's definition.[30] Flammarion [31] states that civil twilight ends and the day closes at the moment when the sun is 6° below the horizon, and the planets and stars of the first magnitude begin to appear. In the Annuaire Astronomique de l'Observatoire Royal de Belgique [32] it is stated that civil twilight ends when the sun is about 6° below the horizon, at the time the [anti]crepuscular arch passes the zenith. Heim [33] states that with a depression of the sun of 6½° civil twilight ends; that is to say, one can no longer read and write without artificial light. According to Vincent [34] civil twilight begins in the morning at the instant when we are first able to read ordinary print with the back turned toward the east; the sun is then 6° below the horizon. It ends in the evening when we cease to be able to read with the back turned toward the sun's setting. A note in the Journal of the Royal Astronomical Society of Canada, May, June, 1916, p. 265, also gives as the end of civil twilight the moment when the [anti]*crepuscular curve* passes the zenith, and planets and stars of the first magnitude begin to appear, the depression of the sun below the horizon being about 6°.

It thus appears that five distinct definitions are given for the ending of civil twilight in the evening or its beginning in the morning, as follows:

(1) The moment when the anticrepuscular, or anti-twilight arch passes the zenith.

(2) The moment when the sun is 6° to 6½° below the horizon. This latter, however, appears to be dependent upon (1).

(3) The moment when stars and planets of the first magnitude are just visible.

(4) The moment in the evening when darkness compels us to suspend labor in the open air, or the moment in the morning when the light is sufficient for its resumption.

(5) With the disappearance of the first purple light in the evening, or with its reappearance in the morning. This, in general, appears to coincide with (2) and observations likewise appear to make it coincide with (3) and (4).

Likewise, there are discrepancies to be found in tables giving the duration of civil twilight. Thus, in the Berliner Astronomisches Jahrbücher for 1776–1783, the tables which give the duration of astronomical twiligh (already referred to) also give the duration of civil twilight; or the interval between the time the center of the sun coincides with the true horizon, disregarding atmospheric refraction, and the time its center is 6° 23½′ below the horizon. In the Annuaire Astronomique de l'Observatoire Royal de Belgique [35] is a table giving the duration of civil twilight for every fifth degree of latitude, at the times of the summer and winter solstices and the equinoxes; and the time given is that required for the center of the sun to pass from the horizon to a point 6° below, *true positions being understood*. This table was copied by Exner.[36] In the Annuaire Astronomique et Météorologique, par Camille Flammarion,[37] is a table that gives the time interval between the instant when the *center of the sun appears to be on the true horizon*, allowing for atmospheric refraction, and the instant when its center is 6° below the horizon; and this table has been copied by Láska.[38]

Finally, in the Ephemerides of the Annuaire Astronomique de l'Observatoire Royal de Belgique is given the time of beginning of civil twilight at Uccle, the time of sunrise, the time of sunset, and the time of ending of civil twilight, for each day in the year. The duration of civil twilight as determined from these data agree quite closely with Flammarion's table, although on some days the duration of morning and evening twilight differs by two minutes. The time given for sunrise or sunset is the instant when the center of the sun will appear to be on the true horizon, assuming 34.5′ for atmospheric refraction.

With the exception of the table in the Berliner Astronomisches Jahrbuch, it is seen that all the above are in accord in considering that civil twilight ends in the evening and begins in the morning when the true position of the sun's center is 6° below the horizon; and the differences found in them, as in the case of tables of the duration of astronomical twilight, are to be attributed to differences in the conception of the position of the sun at sunrise or sunset.

The older definition of the beginning or ending of civil twilight, the moment when the anticrepuscular, or anti-twilight arch passes the zenith, depends on a phenomenon that can only be observed under the most favorable circumstances.[39] It therefore appears that we should abandon this definition for the newer one of Bezold, namely,

[25] Lambert's value for this depression is 6° 23′. See *Lambert*, op. cit., p. 108. The writer is unable to confirm Lambert's use of the terms *civil twilight* and *twilight arch* in this connection, although both terms are repeatedly attributed to him.

[26] *Bravais, M. A.* Observations crépusculaires faites en Suisse, à une élévation de 2,600 mètres au-dessus de la mer. Comptes Rendus, 1884, 18 : 728.

[27] *Abbe, Prof. Cleveland.* Notes from the reports of State sections. MONTHLY WEATHER REVIEW, March 1898, 26 : 114–15.

[28] *Kaemtz*, op. cit., p. 409.

[29] *Bezold, Wilhelm von.* Beobachtungen über die Dämmerung. Gesammelte Abhandlungen aus den Gebieten der Meteorologie und des Erdmagnetismus. Braunschweig, 1906, p. 29. See also Abbe's translation, this REVIEW, p. 620–623.

[30] *Gruner, P.* Nouvelles remarques concernant les lueurs crépusculaires du ciel. Arch. d. sci. phys. et nat., Geneva, 1916, 4me. pér., t. 42, p. 39.

[31] *Flammarion*, op. cit., 1893, p. 29.

[32] See, for example, the Annuaire for 1907, p. 193.

[33] *Heim*, op. cit. p. 63.

[34] *Vincent, J.* Traité de météorologie. Bruxelles, 1914 p. 54.

[35] See, for example, the Annuaire for 1907, p. 194.

[36] *Pernter & Exner*, op. cit., p. 745.

[37] See, for example, the Annuaire for 1893, p. 39.

[38] *Láska*, op. cit., p. 77.

[39] One of the few authentic observations of the transit of the "upper boundary of the earth's shadow" was made by Heim from a steamer in the Indian Ocean. See *Heim*, Luft-Farben, p. 75.

the moment when the first purple light disappears from the sky in the evening or reappears in the morning; since under favorable atmospheric conditions this is a prominent feature of twilight phenomena.

We will therefore define the end of civil twilight in the evening and its beginning in the morning as *the instant when the true position of the sun's center is 6° below the horizon.* At this time stars and planets of the first magnitude are just visible. In the evening the first purple light has just disappeared, and darkness compels the suspension of work in the open air unless artificial illumination is provided. In the morning the first purple light is beginning to appear, and the illumination is sufficient for the resumption of outdoor occupations.

TABLE 2.—*Duration of civil twilight.* (*Interval between sunrise or sunset and the time when the true position of the sun's center is 6° below the horizon.*)

[Minutes.]

Date.	North latitude.														
	0°	10°	20°	25°	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
Jan. 1	22	22	24	25	27	27	27	28	29	30	32	33	34	36	39
11	22	22	24	25	26	27	28	28	29	30	31	32	33	35	38
21	22	22	23	24	26	26	27	27	28	29	30	32	33	34	37
Feb. 1	22	22	23	24	25	26	27	27	27	28	29	31	32	34	35
11	22	22	22	23	25	26	26	27	27	28	29	30	31	33	34
21	21	22	22	23	24	25	25	26	27	28	28	29	30	32	33
Mar. 1	21	22	22	23	24	24	25	26	27	28	28	29	30	31	33
11	21	21	22	23	24	24	25	26	26	27	27	29	30	31	32
21	21	21	22	23	24	24	25	26	26	27	27	28	30	31	33
Apr. 1	21	21	22	23	24	25	25	26	27	28	28	29	30	32	33
11	21	22	22	23	24	25	26	26	27	28	28	29	31	32	34
21	22	22	22	23	25	25	26	27	28	28	29	30	32	34	35
May 1	22	22	23	24	25	26	27	28	28	29	30	32	33	35	36
11	22	22	23	24	26	27	28	29	29	30	31	33	35	36	39
21	22	22	24	25	27	28	28	29	30	31	33	35	36	38	41
June 1	22	22	24	25	27	28	28	29	31	32	34	36	37	40	43
11	22	23	24	26	28	28	29	30	31	33	34	36	38	41	44
21	22	23	25	26	28	29	29	30	31	33	34	36	38	42	44
July 1	22	23	24	26	28	28	29	30	31	33	34	36	38	41	44
11	22	22	24	25	27	28	28	29	31	32	34	36	37	40	43
21	22	22	24	25	27	28	28	29	30	31	33	35	36	38	41
Aug. 1	22	22	23	24	26	27	28	29	29	30	31	33	35	36	39
11	22	22	23	24	25	26	27	28	28	29	30	32	33	35	36
21	22	22	22	23	25	25	26	27	28	28	29	30	32	34	35
Sept. 1	21	22	22	23	24	25	26	26	27	28	28	29	31	32	34
11	21	21	22	23	24	25	25	26	27	28	28	29	30	31	33
21	21	21	22	23	24	24	25	26	27	27	27	28	30	31	33
Oct. 1	21	21	22	23	24	24	25	26	26	27	27	29	30	31	32
11	21	22	22	23	24	24	25	26	27	28	28	29	30	31	33
21	21	22	22	23	24	25	25	26	27	28	28	29	30	32	33
Nov. 1	22	22	22	23	25	25	26	27	28	28	29	30	31	33	34
11	22	22	23	24	25	26	27	28	28	29	30	31	32	33	35
21	22	22	23	24	26	26	27	28	28	29	30	32	33	34	37
Dec. 1	22	22	24	25	26	27	28	28	29	30	31	33	34	35	38
11	22	22	24	25	27	27	28	28	29	30	32	33	34	36	39
21	22	23	24	25	27	27	28	28	29	31	32	33	34	37	39

Table 2 gives the length of the period between the time when the upper limb of the sun appears to coincide with the true horizon and the time the true position of its center is 6° below the horizon. Allowing 16′ for the sun's semidiameter and 34′ for atmospheric refraction the sun is then only 5° 10′ lower than at the time of sunrise or sunset. The length of this interval has been determined in the same manner as the values of astronomical twilight in Table 1. The values of civil twilight thus determined are from 1 to 3 minutes less than the values given by Flammarion, and, likewise, than those that appear in the Ephemerides of the Annuaire Astronomique de Belgique. They are from 3 minutes to 7 minutes less than those given in the above Annuaire for 1907, page 194, which were copied by Exner, and are also less by the same amount than the values given in the table published by me in the Transactions of the Illuminating Engineering Society, 1916 (reprinted in this REVIEW for January, 1916, **44**: 13). This latter table gives, as stated in its heading, the time required for the sun to pass from the horizon to a point 6° below, or vice versa.

Applying the duration of astronomical or civil twilight, as given in Tables 1 and 2, to the time of sunrise or sunset as derived from Weather Bureau Sunshine Tables[40] we may obtain the time of the ending in the evening or of the beginning in the morning of either astronomical or civil twilight as desired.

THE INTENSITY OF TWILIGHT.

With a standard photometer we may measure the intensity of the illumination at intervals during the twilight period, and this has been done by the writer at Mount Weather, Va.,[41] and later, with the same photometer, by Mr. A. H. Thiessen at Salt Lake City, Utah. The results are summarized in Table 3, and are shown graphically in figure 1. The sun's altitude refers to the true position of its center, and has been determined from Ball's Altitude Tables, already referred to.

It is to be understood that the discussion which follows refers to a practically cloudless sky, unless otherwise stated.

TABLE 3.—*Photometric measurements of twilight illumination.*

Mount Weather, Va.						Salt Lake City, Utah.			
Nov. 4, 1913.		Nov. 5, 1913.		Nov. 6, 1913.		Dec. 15, 1914.		May 17, 1916.	
Sun's altitude.	Illumination.	Sun's altitude.	Illumination.	Sun's altitude.	Illumination.	Sun's altitude.	Illumination.	Sun's altitude.	Illumination.
°	*Foot-candles.*	°	*Foot-candles.*	°	*Foot-candles.*	°	*Foot-candles.*	°	*Foot-candles.*
				±0.0	98	−0.6	41.9*h*	+0.5	57.8
−0.6	37					−1.1	20.0	−0.5	32.8
−1.9	13	−1.4	57	−2.0	27	−4.0	1.6*h*	−1.0	23.6*h*
		−2.9	14	−4.2	3	−4.8	0.4	−1.6	17.7
						−5.2	0.12*h*	−1.7	15.2*h*
				−5.9	0.4	−6.2	0.07	−2.2	9.4

Salt Lake City, Utah.

June 6, 1916.		June 7, 1916.		June 10, 1916.		June 29, 1916.	
Sun's altitude.	Illumination.	Sun's altitude.	Illumination.	Sun's altitude.	Illumination.	Sun's altitude.	Illumination.
°	*Foot-candles.*	°	*Foot-candles.*	°	*Foot-candles.*	°	*Foot-candles.*
+0.1	95.8	+ 0.5	57.8	+0.5	55.6	+ 1.6	97.7
−1.2	34.5	− 0.8	58.3*h*	+0.2	46.4	+ 1.1	76.8
−1.8	37.1*h*	− 1.1	33.2	−0.2	45.6	+ 0.8	66.8
−2.6	16.6	− 1.6	55.6*h*	−1.0	25.7	− 0.2	51.0
−3.0	18.3*h*	− 1.8	24.5	−1.4	18.3*h*	− 0.7	29.7
−3.8	7.8 (*a*)	− 1.9	30.8*h*	−2.1	15.4	− 1.0	29.8
−4.4	4.2*h*	− 2.7	8.0	−2.2	18.2*h*	− 1.3	30.3*h*
−6.6	0.63	− 3.0	11.8*h*	−3.0	6.4	− 1.8	19.5
−7.4	0.62*h*	− 4.1	2.3	−3.2	7.4*h*	− 2.6	16.5*h*
		− 4.4	4.5*h*	−3.6	2.8	− 2.9	8.3
		− 4.7	1.6	−3.8	2.7*h* (*b*)	− 3.1	13.6*h*
		− 4.9	2.6*h*	−5.2	0.55	− 3.4	5.6
		− 5.6	0.56	−5.3	1.00*h* (*c*)	− 3.5	8.2*h*
		− 5.9	0.94*h*	−6.2	0.20	− 3.7	4.2
		− 6.5	0.20	−6.4	0.32*h*	− 4.2	4.4*h*
		− 6.7	0.46*h*	−7.3	0.062	− 4.4	2.0
		− 7.3	0.078	−7.4	0.118*h*	− 4.6	2.6*h*
		− 7.4	0.186*h*	−8.3	0.015	− 4.8	1.4
		− 8.3	0.037	−8.6	0.034*h* (*d*)	− 6.9	0.14*h*
		− 8.6	0.069*h*	−9.0	0.008	− 8.0	0.047 (*e*)
		− 9.5	0.015	−9.3	0.016*h*	− 8.6	0.063*h*
		− 9.6	0.027*h*			−10.8	0.004
		−10.0	0.008			−11.4	0.007*h*
		−10.3	0.023*h*				

[40] *Marvin, C. F.* Sunshine Tables. Edition of 1905. Washington, 1905. (W. B. No. 320.)
[41] *Kimball, Herbert H.* Photometric determinations of daylight illumination on a horizontal surface at Mount Weather, Va. MONTHLY WEATHER REVIEW, December, 1914, 42:650-653.

Remarks on Table 3.

At Mount Weather the sun appeared to set when the true position of its center was about 0.7° below the horizon. At Salt Lake City, on December 15, 1914, it appeared to set when the true position of its center was 2.8° above the horizon; and in May and June, 1916, when the true position of its center was about 0.3° below the horizon.

At Mount Weather on November 4, 1913, dense haze prevailed, and at sunset the sun disappeared in a bank of haze; while on November 5 and 6 the sky was clear and the twilight colors were brilliant—yellow with purple light, followed by red.

At Salt Lake City, on December 15, 1914, the sun set clear; on May 17, 1916, the sun was obscured at sunset by Ci.St. clouds, which covered about half the sky; on June 6, 7, and 10 the sky was clear; on June 29 there were a few Ci.St. clouds in the west.

h indicates illumination intensities measured with the photometer tube pointed toward the western horizon; all others were measured with tube pointed toward the zenith.

June 6—(*a*) Moon at 45° altitude.

June 10—(*b*) Venus appeared; (*c*), first star in NE.; (*d*), North Star discernible.

June 29—(*e*) Dipper plainly discernible.

From figure 1 and the notes on Table 3 it is apparent that the twilight is more intense on clear days than on hazy days, and that a cirrus cloud sheet diminishes the light intensity only slightly. Elevated mountains on the horizon near the point where the sun sets diminish the twilight intensity.

The illumination measurements with the photometer pointed toward the western horizon (*h* in the table) do not become markedly higher than measurements with the photometer pointed toward the zenith until the sun is about 2° below the horizon, or shortly before the first purple light begins to appear. The measurements show no increase in illumination during the prevalence of this light. In this respect they are in accord with Gruner's [42] measurements, and disprove many eye observations of an apparent increase in illumination at this time. This apparent increase must be attributed to light contrasts. That part of the sky covered by the first purple light has increased in brightness since sunset, as compared with other parts, and, in consequence, at this time the outlines of buildings and of mountains facing this light stand out with unusual clearness.

From figure 1 it is seen that when the upper limb of the sun appears to coincide with the true horizon (depression of the sun's center 50′) the zenith illumination is about 33 foot-candles. At the end of civil twilight the illumination is about 0.4 foot-candle.

To the unscientific reader light intensities expressed in units of illumination, as above, have little significance. It will therefore be useful to express these intensities in another way.

From two papers by Russell [43] we are able to compare the intensities of sunlight, twilight, moonlight, and starlight with considerable accuracy. Thus, Russell [44] gives the stellar magnitude of the zenith sun as -26.72 ± 0.04 and the stellar magnitude of the zenith moon [45] as -12.55 ± 0.07. The difference in these stellar magnitudes is 14.17. A difference of one stellar magnitude represents light intensities in the ratio of 1:2.512. Therefore, the sun exceeds the moon in brightness 465,000 times. From Weather Bureau photometric measurements made at Mount Weather, Va., Russell [46] obtains for the zenith sun a light intensity of 9,600 foot-candles, or 9.96 stellar magnitudes brighter than a foot-candle, and gives for the foot-candle a stellar magnitude of -16.76. This is 4.21 stellar magnitudes, or 48.3 times, brighter than the full moon in the zenith.

[42] *Gruner, P.* Quelques remarques concernant les lueurs crépusculaires du ciel. Arch. sci. phys. et nat., Geneva, 1914, 37(42):226–248.

[43] *Russell, Henry Norris.* Stellar magnitudes of the sun, moon, and planets. Astrophysical journal, March 1916, 43:103–129.
On the albedo of the planets and their satellites. Ibid., Apr. 1916, 43:173–196.

[44] Op. cit., p. 105.

[45] Op. cit., p. 125.

[46] Op. cit., p. 126–129.

TABLE 4.—*Photometric measurements of moonlight illumination, Salt Lake City, Utah.*

Photometer tube pointed toward the zenith.						Photometer tube pointed toward moon.			
June 13, 1916.		June 14, 1916.		June 15–16, 1916.		June 14, 1916.		June 15–16, 1916.	
105th meridian time.	Illumination.	105th meridian time.	Illumination.	105th meridian time.	Illumination.	105th meridian time.	Illumination.	105th meridian time.	Illumination.
H. m.	*Foot-candles.*	*H. m.*	*Foot-candles.*	*H. m.*	*Foot-candles.*	*H. m.*	*Foot-candles.*	*H. m.*	*Foot-candles.*
9:02 p	0.00451	9:10 p	0.00303*a*	10:28 p	0.00358	11:40 p	0.0127	10:34 p	0.0129
9:13 p	0.00458	9:25 p	0.00400	10:50 p	0.00434	11:53 p	0.0117	10:47 p	0.0127*e*
9:32 p	0.00370	9:43 p	0.00443	11:01 p	0.00546	.....	.....	10:39 p	0.0131*f*
9:34 p	0.00382	9:58 p	0.00424*b*	11:19 p	0.00601	.....	.....	Midn't	0.0143
9:36 p	0.00496	10:14 p	0.00409	11:35 p	0.00555	.....	.....	12:42 a	0.0171
9:41 p	0.00419	10:28 p	0.00424	12:05 a	0.00574	.....	.....	12:45 a	0.0185*g*
10:01 p	0.00468	10:45 p	0.00405*c*	12:24 a	0.00569	.....	.....	12:52 a	0.0174
10:03 p	0.00468	11:00 p	0.00426	12:38 a	0.00574	.....	.....	.....	.....
10:15 p	0.00415	11:15 p	0.00514	12:55 a	0.00707	.....	.....	.....	.....
10:17 p	0.00420	11:33 p	0.00491	12:58 a	0.00707	.....	.....	.....	.....
10:29 p	0.00464	11:47 p	0.00541	.....	.....	.....	.....	.....	.....
10:31 p	0.00582	Midn't.	0.00528*d*	.....	.....	.....	.....	.....	.....
10:35 p	0.00455	.....	.....	.....	.....	.....	.....	.....	.....

Remarks on Table 4.

Clear skies prevailed on all three nights.

Moon full, June 15, 1916, at 2:42 p. m.

Moon on meridian, June 13, 10:44 p. m.; June 14, 11:48 p. m.; June 16, 12:54 a. m. Moon's declination, from $-25°$ to $-26°$.

NOTES.

June 14:

a. 18-point type read with ease;
8-point type read with difficulty.

b. 12-point type read with ease;
6-point type read with difficulty.

c. 10-point type read with ease;
5½-point type read with difficulty.

d. 9-point type read with ease.

June 15–16:

e. 14-point type read with ease;
10-point type read with difficulty.

f. 14-point type read with ease;
10-point type read with difficulty.

g. 12-point type read with ease;
10-point type read with difficulty.

Century expanded type on white paper was used, and the sizes used are illustrated below.

18-point Century expanded type

14-point Century expanded type

12-point Century expanded type

10-point Century expanded type

*10-point Roman type

8-point Century expanded type

6-point Century expanded type

*5-point Roman type

*Approximately 9-pt. and 5½-pt. "Century," respectively.

This result is in good accord with recent measurements made by Thiessen, which are summarized in Table 4. For the total moonlight illumination we must add about 10 per cent for diffuse sky radiation, so that the illumination from the full moon in the zenith as compared to a foot-candle is about 1:43.5. With the moon 66.5° from the zenith its illumination is about 70 per cent of its zenith illumination, and the proportion to a foot-candle is

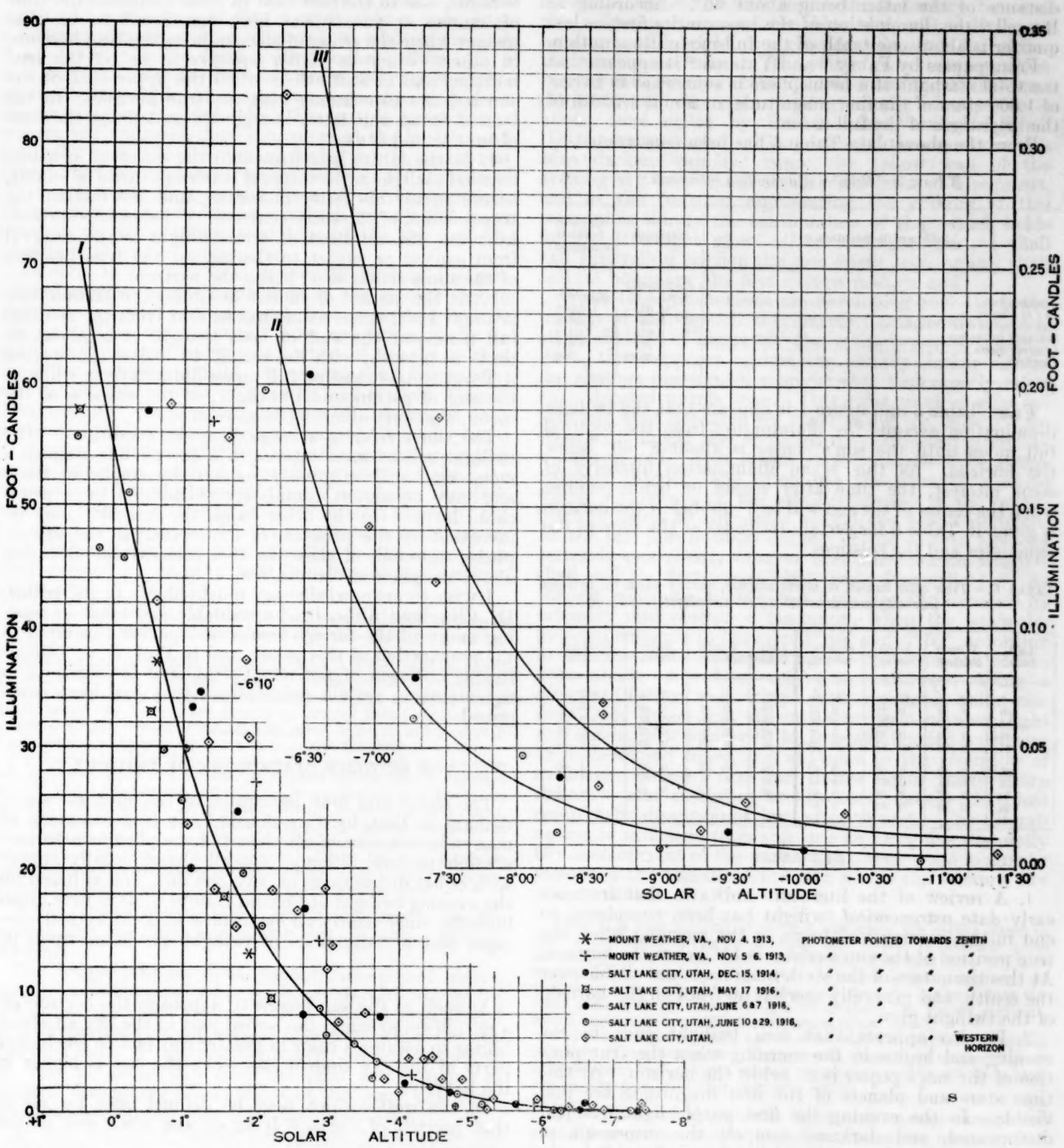

FIG. 1. Photometric measurements of twilight illumination.

Curve I, photometer pointed toward the zenith.
Curve II (insert), continuation of Curve I on more open scale with observations of June 7, 10, and 29, 1916.
Curve III, photometer pointed toward western horizon.
↑ End of civil twilight. True position of sun, 6° 0′ below the sensible horizon.

about 1:62, which is very close to Thiessen's value with the photometer pointed toward the full moon, the zenith distance of the latter being about 66°. According to Russell [47] the illumination of the moon in its first or last quarter is about one-tenth of the full-moon illumination.

From papers by Fabry [48] and Yntema [49] it appears that the total starlight of a hemisphere is somewhat in excess of 1,000 stars of the first magnitude, or about 1/250th of the brightness of the full moon.

From the above data Table 5 has been constructed.

TABLE 5.—*Relative illumination intensities.*

Source of illumination.	Intensity.	Ratio to zenithal full moon.
	Foot-candles.	
Zenithal sun	9,600.0	465,000.0
Sky at sunset	33.00	1,650.0
Sky at end of civil twilight	0.40	20.0
Zenithal full moon	0.02	1.0
Quarter moon	0.002	0.1
Starlight	0.00008	0.004

From Table 5 and figure 1 it appears that the twilight illumination exceeds the illumination from the zenithal full moon until the sun's center is about 8° 40′ below the horizon. As this is an illumination intensity of some interest, the time after sunset or before sunrise when the center of the sun will be 8° 40′ below the horizon is given in Table 6 for certain latitudes at the time of the equinoxes and the solstices.

TABLE 6.—*Time after sunset, or before sunrise, during which the twilight intensity exceeds zenithal full-moonlight.*

Latitude.	Winter solstice.	Equinoxes.	Summer solstice.	Latitude.	Winter solstice.	Equinoxes.	Summer solstice.
°	*H. m.*	*H. m.*	*H. m.*	°	*H. m.*	*H. m.*	*H. m.*
0	0 35	0 31	0 35	38	0 44	0 40	0 49
10	0 35	0 32	0 35	40	0 46	0 41	0 51
20	0 36	0 33	0 37	42	0 48	0 42	0 54
25	0 38	0 35	0 39	44	0 50	0 44	0 57
30	0 40	0 36	0 42	46	0 52	0 45	1 00
32	0 41	0 37	0 43	48	0 54	0 47	1 05
34	0 42	0 38	0 45	50	0 57	0 49	1 11
36	0 43	0 39	0 47				

SUMMARY.

1. A review of the literature indicates that from an early date *astronomical* twilight has been considered to end in the evening and begin in the morning when the true position of the sun's center is 18° below the horizon. At this time stars of the sixth magnitude are visible near the zenith, and generally there is no trace on the horizon of the twilight glow.

2. It also appears that *civil* twilight ends in the evening and begins in the morning when the true position of the sun's center is 6° below the horizon. At this time stars and planets of the first magnitude are just visible. In the evening the first purple light has just disappeared, and darkness compels the suspension of out-door work unless artificial lighting is provided. In the morning the first purple light is beginning to be visible, and the illumination is sufficient for the resumption of out-door occupations.

3. Some confusion has arisen in the computation of tables of the duration of both astronomical and civil twilight, due to the fact that in some instances the time of sunrise or sunset has been considered to be that instant when the *center* of the sun is on the true horizon; in others, when its center *appears* to be on the true horizon; and in still others when the *upper limb* of the sun appears to coincide with the true horizon. In the United States this latter is regarded as defining the time of sunrise and sunset.

4. In the tables here presented the duration of astronomical twilight is the interval between sunrise or sunset, according to this latter definition, and the instant the true position of the sun's center is 18° below the horizon. Likewise, the duration of civil twilight is the interval from sunrise or sunset to the instant the true position of the sun's center is 6° below the horizon.

5. At the instant of sunrise or sunset the illumination is about 1,650 times as intense as that from the zenithal full moon; at the end of civil twilight it is about 20 times as intense; with the sun 8° 40′ below the horizon it about equals zenithal full moon illumination; while at the end of astronomical twilight, in the absence of the moon, it is only about 0.004 as intense.

The above refer to average clear sky conditions. The twilight will be more intense in a dry climate than in a moist one, will be greatly reduced by smoke or haze, and may be almost completely obliterated by a dense cloud layer. On the other hand, the intensity may be increased by the presence of ice crystals in the atmosphere, especially if they are at a considerable elevation above the place of observation.

I wish to acknowledge my indebtedness to the editor, Dr. Cleveland Abbe, jr., for valuable assistance in reading many of the foreign books and papers consulted in the preparation of this paper, and to Prof. C. F. Talman for his criticism of the manuscript, and for bringing to my attention certain publications that had been overooked.

[47] Op. cit., p. 117.

[48] *Fabry, Charles.* The intrinsic brightness of the starlit sky. Astrophysical journal, 1910, 31: 399.

[49] *Yntema, Lambertus.* On the brightness of the sky and the total amount of starlight. Groningen, 1909. 4° p. 37.

VON BEZOLD'S DESCRIPTION OF TWILIGHT.[1]

The oldest and best description of the phenomenon of twilight is that by von Bezold.[2] It is a summary of many observations of all phases of the phenomenon into a single picture, although not all phases usually appear with equal distinctness on any one day, and is based on the evening twilight of Central Europe.[3] It is here given literally, since nearly all systematic and theoretical concepts and investigations of twilight are based upon it.

As soon as the sun begins to approach the horizon on a cloudless [4] evening, the lowest part of the sky all about begins to assume a color in greater contrast to the higher parts of the sky than it has when the sun is higher in the heavens.

In the west—which may be defined once for all as that portion of the sky lying on the sun's side of the

[1] Translated from *Pernter & Exner.* Meteorologische Optik, IV. Abschnitt. Wien, &c., 1910. Pp. 745–751, 754–755. By C. Abbe, jr.

[2] Poggendorff's Annalen, 1864, 123:240-276. Republished in full on pp. 1–30 of *von Bezold's* "Gesammelte Abhandlungen aus den Gebieten der Meteorologie und des Erdmagnetismus. . . ." Braunschweig, 1906. viii, 448 p. 4°.

[3] In von Bezold's "Gesammelte Abhandlungen", p. 2, he states this description to be based largely on 24 observations by himself at Munich from Oct. 20, 1863, to Apr. 15, 1864.

[4] "Cloudless" (wolkenfrei) as here used indicates only the absence of greater cloud masses, particularly in the western and eastern skies. Detached small clouds, particularly if located in the north and south, of course can not influence the general course of the phenomenon.—"Gesammelte Abhandlungen," p. 2, footnote 1.

sun's vertical, while the eastern sky lies on the opposite side—this color is at first an extremely transparent white which changes to yellow in the course of time. On the north and south it is at first a weak then a somewhat stronger and more opaque ocher-yellow, while in the east it gradually changes from a dirty ocher-yellow into a dull purple. Close to the horizon the coloring is everywhere duller, while at a somewhat greater altitude a clearer stratum is noticeable. The purple tones in the eastern sky approach gray ash colors at the horizon and gradually pass into the blue at higher levels, so that at sunset they are no longer recognizable at an altitude of 6° to 10° (depending on the state of the atmosphere). There often appears a brighter whitish to yellowish layer between the clear transparent blue of the sky and the opaque purple near the horizon.

As soon as the sun sinks below the horizon the ash-colored shadow of the earth rises in the eastern sky in the form of the *dark segment*, first described by De Mairan.[5] This dark segment now appears actually to shove itself up over the purple portion of the sky so that the latter becomes a visibly decreasing zone forming *the first eastern twilight arch* or the *first anti-twilight* (Gegendämmerung). Since the upper part of this bright zone executes little or no upward movement, it is displaced or covered sooner or later by the dark segment according as the latter has reached a lesser or greater height. As soon as this brighter zone no longer separates the dark segment from the already rather dark sky above it, the boundary of the segment is no longer observable; at its best the arch-like area corresponding to the segment is distinguished by its ashy tone from the higher portions of the sky. * * *

I have never been able to trace the dark segment higher than to an altitude of 12°, usually it disappeared from my sight when at but half that height.

As for the form of the dark segment, I think it is very well described by this name. Its boundary is an arc that probably approaches rather closely that of a great circle. The two limbs, however, which should touch the horizon are usually so blurred that I do not trust myself to decide whether they are 180° apart or not so much, though I am inclined to believe the latter to be nearer the truth.

The boundary of the dark segment is best determined near its summit, and even there it is not sharply defined except after it has risen 1° or 2° above the horizon and until a little while before it disappears entirely. Close to the horizon one usually observes a gray layer, probably due to haze, smoke, etc., and easily causing mistakes, so that often one thinks he sees the dark segment some time before sunset, which is of course quite impossible. Under the most favorable circumstances the boundary of the segment may indeed be determined to within 10 or 6 or perhaps even fewer minutes of arc. * * *

While these observations are being made on the eastern sky, the following phenomena are taking place in the west:

The bright whitish light, already mentioned above, spreads before sunset to a considerable altitude in the vicinity of the sun's vertical. This vertical expansion I noticed particularly on several occasions while the sun was still about 4° above the horizon; also, it seemed to me that at about this time the light had a touch of purple. In making observations of this point one must, of course, screen the eyes from the direct sunlight.

As the sun more closely approaches the horizon the whole western sky, from the horizon up to an altitude of 8° or 12°—depending on the condition of the atmosphere—takes on an increasingly pronounced yellow hue (Färbung) which often grades into a red or even brownish red close down to the horizon line. At the same time there remains above the sun a bright and extraordinarily transparent spot of [lesser] vertical but relatively great horizontal extent, which forms the boundary between the yellow portion and the blue sky, which latter to be sure is still bright to a considerable altitude. After the sun has actually set, the yellow grows deeper, often turning into orange, while the transparent spot increases its horizontal dimension and gradually changes to a bright zone called by Brandes the "twilight glow" (Dämmerungsschein). The portion of the sky above this zone darkens rapidly. Since the yellow wall of the evening sky later takes on also the form of a segment, and as the function representing the sinking of this segment is simply the continuation of that which holds for the "twilight glow" (Dämmerungsschein), I shall call this yellow portion the *first bright segment* and shall call its boundary the *first western twilight arch*.

While these phenomena are developing over the lower portion of the western sky, purple tones are developing at an altitude of about 25° above the [western] horizon. First, there appears against the already darker sky at the altitude mentioned, a bright spot that rapidly takes on a decided purple tone. This color most closely approaches that obtained by superposing the ends of two spectra; it might also be called rose-color and often has a dash of red. This bright spot broadens with extraordinary rapidity and often has the form of a circle which, by reason of the steady increase in its radius, literally seems to slip down behind the yellow segment. As the last purple tones die out of the eastern sky one certainly can clearly observe this phenomenon which I shall call *the first purple light* (erste Purpurlicht).[6] As the sun continues to sink this light greatly increases its intensity and reaches a maximum when the sun's depression amounts to between 3° 40′ and 4° 50′, according to my observations, depending on the condition of the atmosphere. At about this time buildings having a westward-facing wall which had appeared quite dim soon after sunset and shown no contrast between light and shade, now appear to be brightly flooded with rosy or flesh-colored tones, the analogue to the afterglow of mountain ranges. One can notice again fairly sharp shadows, and recognize architectural details that had completely disappeared just after sunset. This illumination is sufficient to enable one to recognize distinctly the development of the purple light, even when in narrow streets in the middle of the city where the western sky is not visible.[7] * * *

While it is very difficult to observe accurately the earlier stages in the development of the *purple light*, and further it proceeds quite differently on different days, nevertheless after that time when it approaches its maximum intensity the course is fairly regular. At that time, with a cloud-free (reinem) sky the light has an almost circular form with its center lying a little above the yellow segment, which appears to cover the lower portion of the circle. * * *

Above the bright segment, and on either side the purple light, appear two light blue-green areas. The greenish tinge there always present does not arise from contrast effects, as one may readily convince himself by screening out [other sources of light]. * * *

The center of the purple light now moves downward rapidly and its radius steadily increases; soon it has assumed the form of a semicircle whose center lies in

[5] *Mairan, J. J. D. de.* Traité physique et historique de l'aurore boréale. 2de éd. Paris, 1754. pp. 400–403. The original description is reprinted and translated on p. 623–4 of this issue of the REVIEW.

[6] Colored illustrations of the purple light and other twilight phenomena may be found in—

Annali, Uff. Cent. Met. Ital., ser. 2, v. 7. pt. 1, 1885.

Kiesling, J. Untersuchungen über Dämmerungserscheinungen zur Erklärung der nach dem Krakatau-Ausbruch beobachteten atmosphärisch-optischen Störung. Hamburg, &c. 1888. vi, 172 p. 4°. Notably Tafel 5.

Heim, Albert. Luft-Farben. Hofer & Co., Zürich, 1912. 93p. 19 col. illust. Particularly figs. 16, 17, 18, 21.—C. A., jr.

[7] As to the true photometric intensity of this illumination see Kimball's figure 1 and his remarks on p. 618.

the boundary of the bright segment; and finally this light becomes a narrow zone of very slight altitude, but of more significant linear extent. The bright [yellow] segment is then bounded sharply by this zone, which is properly so called from this time on. This boundary is *the first western twilight arch.*

At about the time when the first purple light contracts to that narrow zone, and is soon to disappear altogether, there occurs that strikingly rapid decrease in the general daylight which is regarded as *the end of civil twilight.* At this time the sun's depression is about 6°. * * *

The [purple light] often embraces long dark-blue, even greenish, stripes [crepuscular rays] converging toward the sun. These stripes, mentioned already by Howard, are really the shadows of clouds below or close to the horizon as he supposed, which is best shown by the fact that one often has the opportunity to observe the clouds causing them, as well as the the shadows from the clouds. On perfectly cloudless days, when these stripes always develop quite late, they may well be due to terrestrial objects. These stripes are of interest, because as soon as they appear the contrast permits one to observe that the purple tones extend much higher than otherwise they would appear to do. If these stripes do not appear until the purple light has sunk far down, and this is usually the case, then one sees it again suddenly in portions of the sky whence one believed it to have long since disappeared. Thus it appears, in such cases, that the purple light is really still present behind the yellow bright segment; in other words, that the purple light owes its development to higher atmospheric strata than does the bright segment. Under these conditions the boundary of the latter is scarcely recognizable. When the purple light has wholly disappeared the two light blue-green wedge-shaped areas, spoken of above, still remain long visible, probably the most striking proof that here we have not a case of subjective deception. * * *

As soon as the purple light has disappeared, and if there are no shadow stripes present, the altitude of the bright segment may be determined with some accuracy, perhaps to within 10 or 15 minutes of arc. According to my measurements the sinking of the segment keeps rather close step with that of the sun, so that if $-\omega$ is the sun's altitude or ω its depression, θ the altitude of the summit of the bright segment we have the equation

$$\omega+\theta=\gamma,$$

where γ is a constant whose value differs on different days and, according to my observations, varies between 8° and 12°. This empirical formula may be extended to the first portion of twilight when only the twilight glow forms the, to be sure, poorly defined boundary of the bright segment.

If now, one turns his attention again to the eastern sky, the latter is found to have a slight general coloration, or at least to be illuminated, and he will also probably discover traces of *a second dark segment* which rises from the horizon about the time when the purple light has completely disappeared or has contracted to the above described hazy stratum.

This second coloring is often scarcely sufficient to permit of its presence being certainly determined, and during my observations it was never intense enough to permit any accurate measurement of the altitude of the second dark segment. Clouds observed in this second illumination of the eastern sky seemed to me to shade off rather more gradually as though overtaken by the edge of a shadow. The second dark segment disappears again, though at a somewhat greater altitude above the horizon, just as did the first [dark segment].

In the western sky, however, there is preparing a repetition of the phenomena already observed. Thus, while the first twilight arch is descending—in accord with the law stated—there is gradually developing at an altitude but little lower than that where the first twilight arch appeared, a second but less brilliant phenomenon of the same kind. The first twilight arch gradually loses its dull-purple boundary, without decreasing in sharpness, however, and above it there appears a somewhat dull greenish-yellow layer against the upper part of which there stands out a brighter zone—the *second twilight glow* or *second western twilight arch*, which is the boundary of the *second bright segment.* On a number of occasions I have observed both arches showing most distinctly one above the other.

Above this arch there develops, under favorable conditions, a *second purple light*, perhaps at a somewhat lesser altitude than did the first but with quite the same sequence of changes, although its color is more in the yellow-red. Sometimes I have seen this second purple light quite intense, e. g., on November 18, 1863 [at Munich], when it was stronger than the first light often is. A number of times the second light was fairly decided, but on most days I did not see it at all.

The time of maximum intensity can be determined but imperfectly, because of the greatly decreased sharpness of the phenomenon; however in the four cases when such a determination was made the result was remarkable. On each occasion the sun's depression at the time of the maximum of the second purple light was almost 2.2 times as great as that corresponding to the maximum of the first purple light, although the latter depression had very divergent values on the four days.

Finally, the second purple light also disappears in a manner analogous to that of the first, sinking down behind the second bright segment which is now the only remaining illuminated portion of the sky and whose disappearance marks *the end of astronomical twilight.* * * *

It was not until my later series of observations that I became aware of the fact that from the instant when the sun stands about 7° below the horizon onward, the portion of the sky which still receives any light at all from the sun is fairly well distinguished from the already perfect night sky of the east. This latter is probably the continuation of that same first dark segment which earlier had disappeared from our sight and now reappears after it has already passed to about 30° west of the zenith. At this time it embraces more than half the horizon and rapidly sinks like a black veil until it merges with the second western twilight arch, the latter meanwhile holding undisturbed to its own downward course. * * *

Concerning this account by von Bezold, Exner goes on to say [8] that this is the first detailed description of the normal twilight, although it had been observed and discussed from a much earlier date. Von Bezold has sharpened the concepts of the individual phases or phenomena and gave them the names which we shall employ in the senses already indicated. * * *

Accurate determinations of the colors observed rarely have been made, only a very few spectroscopic measurements exist. * * *

Before describing in more detail the position of the phenomena in the sky and their time of occurrence with reference to the sun's position, we shall summarize the individual phases chronologically, following von Bezold's system.[9]

(*a*) *First anti-twilight or Gegendämmerung.*[10]—This is seen in the eastern sky at sunset and in the western sky at sunrise, the sun being close to and either above or below the horizon. We shall use the term also for [the western phenomenon] at dawn although the anti-twilight thus defined is the second chronologically. Here and elsewhere we would apply the designation "*first*" to the

[8] *Pernter & Exner.* Meteorologische Optik, pp. 751, 754.

[9] A recent classification of the successive "twilights" is put forward by Prof. *F. E. Paul Gruner* of Bern who recognizes four main twilights, viz, Diurnal, Civil, Astronomical, and Nocturnal. He also gives useful hints for those wishing to contribute further observations on this little-studied subject. (*See* Nouvelles remarques concernant les lueurs crépusculaires du ciel, *in* Arch. d. sci. phys. et nat., Genève, 1916, 4me pér., t. 42, p. 32-46.)—C. A. jr.

[10] The term includes the eastern twilight arch (at sunset; western, at sunrise) and the dark segment. It would be less confusing if we followed Mairan by calling the twilight arch opposite the sun the anticrepuscular or anti-twilight arch.—C. A. jr.

principal phenomenon as being more frequently and more readily observed than is the "*second.*"

(*b*) *Twilight glow or Dämmerungsschein.*—The same remarks apply to the twilight glow which lies above the sun's position. As soon as the sun is several degrees below the horizon, however, the glow is no longer (or not yet) visible.

(*c*) *First twilight arch.*—The first twilight arch, the boundary of the first bright segment, lies in the west in the evening, in the east in the morning. It is visible when the sun stands below the horizon.

(*d*) *First purple light.*—The first purple light appears over the first twilight arch, in the evening it appears almost immediately after the disappearance of the first Gegendämmerung, while in the morning the reverse order occurs.

Civil twilight ends, in the evening, at the setting of the first purple light, and begins in the morning at the rise of the same.

First twilight is the name frequently applied to all the above phenomena from (*a*) to (*d*) collectively; in distinction to these is the series which follows under (*e*) to (*g*), known collectively as the *second twilight.*

(*e*) *Second anti-twilight or Gegendämmerung.*[11]—The second anti-twilight begins, in the evening, in the eastern sky about the end of civil twilight; conversely in the morning it ends in the west at the beginning of civil twilight.

(*f*) *Second twilight arch.*—This arch, which forms the boundary of the second bright segment, appears in the evening after the setting of the purple light. In its initial stage it is simultaneously visible in the western sky with the first arch; the inverse condition occur in the morning.

(*g*) *The second purple light.*—The second purple light appears above the second twilight arch. In the evening it sinks behind, and in the morning it rises from behind that arch.

Astronomical twilight ends with the setting of the second twilight arch; in the morning this twilight begins with the rising of that arch.

MAIRAN'S DESCRIPTION OF ANTI-TWILIGHT.

Elsewhere in this issue reference is made [1] to the first published description of twilight phenomena where the dark segment and the first anti-twilight arch—as observed in the east on a good day soon after sunset—are given their present names. This description was by Mairan, who published it in a somewhat inaccessible work [2] that happens to be in the Weather Bureau library. It also contains a reference to what is perhaps the earliest printed mention of the phenomena.

We reprint the French passages with a translation; our French version follows the original closely, except in capitalization and in the use of the sign "&". A marginal reference in the original is here given as a footnote, and * * * indicate omissions of passages not bearing on the description proper.—C. A. jr.

XII^me^ ÉCLAIRCISSEMENT.

Sur l'Anticrépuscule.

Qu'il me soit permis, pour abréger, de nommer ainsi un phénomène qui ne manque presque jamais de paroître dans les jours sereins avec le crépuscule, et qui lui est opposé, non seulement par le lieu du ciel qu'il occupe, mais encore par le renversement de sa partie lumineuse, d'autant moins vive qu'elle est plus prés de l'horizon.

Il ne faut que regarder le ciel un peu avant le lever du soleil, ou quelques minutes après son coucher, pour reconnoître le phénomène ou le météore dont il s'agit. Il est très-visible, et vrai-semblablement aussi ancien que le monde; et il y a tout lieu de s'étonner, qu'il n'en soit pas parlé davantage dans les livres de physique ou d'astronomie, tant anciens que modernes. Je n'en connois qu'un où il en soit fait mention expresse, et qui fut imprimé à Ulm en 1716, ayant pour titre *des Couleurs du Ciel.*[3] M. Cramer, qui avait très-bien remarque l'anticrépuscule, et qui avoit même fait quelques recherches d'optique sur ce météore, s'étonnoit comme moi du silence des auteurs à cet égard. Il m'en écrivit il y a plusieurs années, et je lui communiquai ce que j'en savois, avec la note du livre de Funccius. D'autres occupations l'empêchèrent sans doute de pousser plus loin se recherches, ou de les publier. Heureux, si je pouvois encore consulter sur ce sujet, comme sur toute autre matière, un ami si fidèle, si sage si éclairé, et dont je regretterai éternellement la perte.
* * *

On remarquera donc le soir d'un beau jour, au coucher du soleil, par exemple, ou quelques minutes après, à la partie opposée du ciel et immédiatement sur l'horizon, une espèce de bande ou de *Segment obscur,* bleuâtre et pourpré, surmonté d'un *arc lumineux* et coloré, blanche-âtre, orangé, et enfin couleur de rose à son bord supérieur, tirant quelquefois sur le couleur de feu. Car ces couleurs, ou plûtôt ces nuances des couleurs vraies n'y sont jamais ni bien tranchées ni bien décidées. Ce n'est aussi que par des circonstances plus ou moins favorables, selon que l'air est plus ou moins dégagé de vapeurs, d'exhalaisons et de nuages, que l'anticrépuscule d'un jour, ou d'un climat, differe de celui d'un autre. Du reste, rien n'est plus uniformément constant que ce phénomène, qui est purement optique, et en cela bien différent de l'aurore boréale, dont le sujet est physique, mais variable et accidentel. * * *

Cependent le soleil s'enfonce encore sous l'horizon, le crépuscule s'abaisse, et l'anticrépuscule s'élève d'autant; les rayons du soleil qui alloient frapper la voûte au zénit ou près du zénit n'y parviennent plus, ils se réfléchissent sur des points plus proches du soleil, et l'anticrépuscule s'élève encore; son arc lumineux et coloré se détache du segment bleuâtre et pourpré, qui ne demeure bien-tôt que gris ou cendré, il mont toûjours et parvient enfin jusqu'au zénit, où il est encore sensible lorque l'air y est pur; car après être monté jusqu'à une certaine hauteur, il s'affoiblit de plus en plus, et disparoît enfin totalement. J'ai observé l'anticrépuscule une infinité de fois dans les parties les plus méridionales de la France, à Paris et aux environs.

La bande bleuâtre et pourprée de l'horizon ne demeure plus que grise et cendrée, lorsque l'arc anticrépusculaire [5] s'en est détaché, parce que les rayons rouges du soleil et de la partie la plus brillante du crépuscule ne s'y réfléchissent plus. * * *

[Translation.]

On the anti-twilight or anticrepuscule.

Permit me, for the sake of brevity, to thus name a phenomenon that almost never fails to appear on fine days (jours sereins) at twilight, and which is opposite to this latter not only as to location in the sky but also

[11] This term includes the second eastern twilight arch (at sunset; western at sunrise) and the second dark segment.—C. A. jr.

[1] Von Bezold's description of twilight, p. 621.

[2] *Mairan, [Jean Jacques Dortous] de.* Traité physique et historique de l'aurore boréale. Seconde édition, Revûe, & augmentée de plusieurs éclaircissemens. Paris, Imprimerie royale, (1754). (Suite des Mémoires de l'Académie Royale des Sciences, Année M.DCCXXXI.) [xii], 570, xxij p. 17 pl. 25½ cm. pp. 400–403.

[3] *Funccius, Joh. Casp.* De coloribus cœli. Ulm, 1716. Sect. IV, §xxx.

in the reversed position of its luminous portion, decreasing in brightness as the horizon is approached.

One need but to observe the sky a little before the rising of the sun, or a few minutes after it has set, to recognize the phenomenon or meteor [4] with which we are concerned. It is very plain, and probably as old as the earth itself; and there is every reason for astonishment that it does not receive more attention in both the modern and ancient works on physics or astronomy. I know of but one work where it is expressly mentioned, and that is a work entitled "On the Colors of the Sky." [5] M. Cramer—who had indeed well observed the anticrepuscule and had even made some optical studies on it—was as surprised as I at the silence of writers in this respect. A number of years ago he wrote to me on the subject, and I communicated to him what I knew thereof together with the note on the work by Funccius. No doubt other occupations prevented him from carrying his researches farther, as well as from publishing them. Happy would I be might I still consult on this, and all other subjects, a friend at once so faithful, so wise, so enlightened and whose loss I shall eternally regret. * * *

On the evening of a fine day, then, one will observe at sunset or a few minutes after, in that portion of the sky opposite the sun and immediately on the horizon, a kind of band or *dark segment* of bluish and purple color surmounted by a *luminous* and colored *arch* which is whitish, orange, and finally on its upper border of a rose color sometimes verging on fire color. For these colors, or rather these shades of true colors are never well, clearly, or sharply defined here. Also, it is only under more or less favorable circumstances, according as the air is more or less free from vapors, exhalations, and clouds, that the anticrepuscule of one day or of one climate differs from that of another. Otherwise there is nothing more uniformly constant than this phenomenon, which is a purely optical one; therein quite different from the aurora borealis which belongs to physics but is variable and accidental. * * *

Now as the sun sinks below the horizon, the twilight or crepuscule sinks, and the [anti-twilight or] anticrepuscule rises by a corresponding amount; those solar rays that had been striking the vault at or near the zenith no longer reach so far, they are reflected from points nearer the sun, and the anti-twilight continues to rise; its luminous, colored arch detaches itself from the bluish, purple segment which soon shows nothing but a gray or ash shade, it [the colored arch?] mounts steadily and finally comes to the zenith where it is still visible when the air is there clear; for after having attained a certain elevation it grows weaker and weaker, until at last it totally disappears. I have observed the anti-twilight innumerable times in the more southern portions of France, at Paris, and in its environs.

The bluish and purple band at the horizon becomes gray and ash-colored when the anti-twilight or anticrepuscular arch [6] detaches itself therefrom, because the red rays from the sun and from the more brilliant portion of the twilight (crépuscule) no longer are reflected so far downward.

[The author also remarks that while the secondary rainbow is frequently observed, he is not aware that a secondary anti-twilight arch has ever been seen.—C. A., jr.]

[4] *I. e.*, "Any phenomenon or appearance in the atmosphere," the first significance of the word.—*Transl.*

[5] It is interesting to note here that Mairan uses the name "anti-twilight arch" not less than 4 times in this Eclaircissement.—*Transl.*

EXPLANATIONS OF THE WESTERN PURPLE LIGHT AND THE EASTERN AFTERGLOW (NACHGLÜHEN).[1]

By ALBERT HEIM.

[Translated for the MONTHLY WEATHER REVIEW by C. Abbe, jr.]

All observations of the phenomenon point to the conclusion that the western purple light (Westpurpur) is the condition necessary for the afterglow (Nachglühen). If the western purple light does not appear, then the afterglow in the east is always absent; and if the western purple light is very weak, then one sees hardly a weak suspicion of the afterglow.

Wolf, who was the first to study the alpenglow with exactness, reached the conclusion—which is confirmed by Maurer—that the evening glow of the western sky, which we see projected into the high air layers as the western purple, was reflected at a sharp angle from the mirroring undersurfaces of high air layers. Mirror reflection does not essentially change the color of the light falling upon the mirror, but the width of the effective surface and the breadth of the bundle of rays prevents the production of sharp shadows. Therefore, a portion of the evening red (Abendrot) is reflected downward once more into the blue earth shadow. If this is the manner in which the afterglow originates, then the name "reflex glow" (Spiegelglühen) is justified.

If the afterglow (Nachglühen) is a reflex glow, then we may compute the altitude of the mirroring air layers. The results give altitudes of only 20 to 35 km. for the afterglow at a solar depression of $4\frac{1}{2}°$ to 6°, and of 70 to 80 km. for a depression of 9°. The different phases of the afterglow correspond to mirroring layers at different heights.

It seems to me that the following explanation of the afterglow is also a possible one:

The upper air layers receive almost solely yellow-red, they are directly illuminated by the yellow-red. The air reflects diffusely not simply blue *alone*, but all colors, as is shown by the whitish appearance along the horizon; however, it reflects more of blue than of the other components of white light. If it receives yellow-red almost exclusively, then it must also reflect diffusely the yellow-red, of course weakened. Thus there originates throughout the whole zone of air standing in the earth's shadow *a diffuse evening red* (Abendrot) *below the directly illumined evening red*. This is at one and the same time the purple light in the west and the afterglow in the east. In the purple light we see nothing other than the higher air layers illumined by the evening red from the sun. Yellow-red illumination of the air appears as purple-red. And the afterglow in the east is the reflection (*Widerschein*, Reflex, Abglanz) of the western purple.

Finally, there is support for the probability that diffraction affects the light rays shining down to us from the higher and still directly illumined air layers at the time of the purple light and the afterglow. Kiesling, Pernter, and Riggenbach, particularly have assumed that diffraction was the cause of the western purple light. According to Riggenbach's observations after the eruption of Krakatoa it was very clear that the purple light resulted from the widening of Bishop's Ring, which latter certainly owed its copper-red-brown to the light's diffraction by dust particles. It seems to me that mirror-reflection and diffuse reflection send the light down to us

[1] *Heim, Albert.* Luft-Farben. Hofer & Co. A.-G, Zürich, 1912. 8 cm. pp. 70–74. [Notable illustrations in color!]

from the higher illuminated air masses and that diffraction can influence only the color of the light.

The color and the time of occurrence of the western purple light and of the afterglow are in agreement with all three classes of explanations. The relative rarity of the afterglow and its varying intensity with the position of the sun speak in favor of the idea of mirror reflection. It seems to me, however, that if the cause were mirror reflection from the sunset zone the light would appear somewhat less scattered and would give more light and shade effect in the mountains. As a matter of fact I have often wondered, as I stood in the mountains in the afterglow itself, at the shadowless or very weakly shadowing character of this peculiar flesh-red light; and how it often appears not merely as the western purple and the eastern afterglow but fills the whole intervening space with its all-pervading, mysterious, gloomy yellow-red. The breadth of the light-giving surface and of the mirror together are after all an inadequate explanation, it seems to me, for this diffuse behavior of the afterglow. Just as the sky is blue and the mountains and valleys are filled with blue haze during the day, so now the sky is purple, copper-colored, or reddish yellow and the mountains and valleys are filled with these colors. If reflection throws the western purple light into our eyes and upon the eastern mountains, then there must be a much stronger polarization of the purple.

If the sky's blue were a true fluorescence of the air, then the western purple light and the afterglow would be blue instead of red. I conclude, from their colors, that the sky's blue is merely a pseudo-fluorescence.

The peculiar form of a "salmon-colored spot" in which the western purple light often begins, has not yet been explained, while the arched form of the western purple seems to be a matter of course. Evidently we have not yet the last word in explanation of the western purple light and of the afterglow. In the case of the afterglow we may have to do with the combined effects of several factors. Nature is, indeed, always more complicated than we like to assume in thought. One thing is quite certain, *the afterglow on the eastern mountains and the eastern sky is* not a direct evening red, but *an indirect evening red which is brought down into the earth's shadow by mirroring or diffuse reflection and diffraction.* Put more simply: The afterglow in the east is the reflected splendor of the western purple light. We may therefore describe the afterglow also as an indirect alpenglow. Here also is repeated a relation similar to that of the first alpenglow: The west furnishes light and color, the east is illuminated thereby. Thus it comes about that light and color are stronger in the west than they are simultaneously in the east. If one stands on the eastern mountains and wholly in the afterglow, there appears no repetition of sunset in the west; one sees only a great surface of purple light spread over almost the whole western sky.

Here and there a sheaf of divergent rays [crepuscular rays] from a mountain or a cloud in the western sky, reaches high up into the recently empurpled heavens. (See Heim's fig. 18.) The shadow rays [or crepuscular rays] appear blue-green in the purple. Hence one may conclude that the air that appears to be already in the western purple, as we stand down below it, still receives direct rays from the sun at high levels above us. The western purple light therefore arises first from direct illumination of the upper air layers. Diffuse reflection and diffraction are but the processes that conduct the splendor down to our eyes in the earth's shadow or across to the mountains.

This does not enable one to decide, however, whether the purple light originates in the west behind the cloud or only on our side of the latter. If the former, then the clouds intercept the purple-colored solar rays; if the latter, then the purple does not develop where the cloud's shadow falls. The former appears to me much the more probable case.

The western purple light, then, seems to be the evening glow of the higher air directly illumined by the setting sun, reflected down into the earth's shadow to our eyes. The eastern afterglow shows us mountains and air indirectly illuminated by the reflection of this lofty evening glow.

TWILIGHT PHENOMENA IN ARIZONA, SEPTEMBER TO DECEMBER, 1916.

By Prof. ANDREW ELLICOTT DOUGLASS.

[Dated: Department of Physics and Astronomy, University of Arizona, Tucson, Dec. 2, 1916.]

[In his letter transmitting this paper Professor Douglass corrects his statement, quoted by me in the REVIEW for August, 1916, 44:434, to the effect that red sunsets were not observed by him after the middle of September, 1916. His accompanying description of twilight colors is closely in accord with the classical description by von Bezold, which, together with Exner's classification of the twilight phenomenon will be found translated on pages 620 to 623 of this number of the REVIEW. Therefore, with the consent of Professor Douglass, I have inserted in brackets in his text the designation given by Exner to the phase of the twilight described. Thus, [(c) First twilight arch] is to be interpreted as meaning that the phase of twilight under consideration will be found under (c) of Exner's classification to have the designation here given.—*H. H. Kimball.*]

From September 16, 1916, to the present time the writer has watched every evening after sunset for the occurrence of bright twilight and afterglow colors, and shadow phenomena. The clearness of our atmosphere permits all these phenomena to be seen with greatest ease down to our horizon of mountains, which averages about one degree in elevation in all directions. From west-northwest to west-southwest the average height is about 1.8°, while in the northwest the apparent horizon descends a very slight amount below the true horizon. In the east the mountains rise from 1° to 2° above the true horizon.

On account of the clearness of the air the sun is never under any circumstances faint enough to be looked at directly by the naked eye. Clouds are rare and two levels of clouds still more rare, so that it becomes possible to estimate cloud heights by the time when direct sunlight ceases to illuminate them. It thus becomes possible here to use means of investigation that would seem incredible to an observer accustomed only to Atlantic coast conditions.

Out of 80 nights, clouds have interferred to a serious extent on only 6 nights. Slight cloudiness has prevailed on over 50 per cent of the nights. In fact, it is a condition of a few thin, scattered cirrus clouds that is most favorable to the beautiful ray phenomena so often noticed. [See Abbe's translations of Heim's and Bezold's descriptions of these crepuscular rays; this REVIEW, p. 622 and p. 625.]

As soon as the disk of the sun is behind the western mountain, a heavy bronze area [(b) Twilight glow] is apparent extending to a distance of 4° or 5° in all directions from the sun itself. At first this bronze is of a rather yellowish color, which soon changes to a reddish tone, lasting some 20 minutes after the disappearance of the sun.

After the sun has really set the clear western sky in that general vicinity shows a structure which seems likely to be due to a high layer of haze in the atmosphere. This structure usually appears as a faint, soft etching of large numbers of parallel lines. In general

these lines have a slight inclination from the horizontal, the northern ends being a little lower than the southern ends. The lines vary in size from a quarter of a degree in width and several degrees in length up to 1° by 10° or even larger. Near the horizon the size is always small, growing larger at the higher elevations. The conspicousness is very different on different nights and the view is always improved by good field glasses. A number of observations have been made on the motion of this detail, which in every case has been in a southerly or southwesterly direction, and a very rough analysis of the rate has given something in the neighborhood of 60 miles per hour. This structural effect, of course, exists in what otherwise appears to be an absolutely clear sky. It rises about 25° high in the west and may be traced through an azimuth of 60° or 75°. The passing of the colored sunlight across this structural detail, lower and lower towards the western mountains, was one of the first phenomena noted last September.

Five minutes after sunset the blue arch of earth shadow [(*a*) Dark segment] begins to rise above the eastern horizon with a brilliant pink curve [(*a*) First anti-twilight arch] of sunlit atmosphere immediately above it. If the night is favorable the pink arch is cut up into a large number of alternating blue and pink rays [see Abbe's translation of Heim's description, this issue of the REVIEW, p. 625] all pointing toward the spot opposite the sun. Twenty-three blue shadow rays have been counted at one time. Some of them may come from clouds visible above the western horizon and the blue shadow may be traced completely across the sky from western cloud to eastern arch. Often the shadow comes from clouds below the western horizon; but at this early moment in the evening, it can not usually be traced nearer the western horizon than 30°.

As the pink arch in the east [(*a*) First anti-twilight arch] rises higher and higher above the horizon, reaching an elevation of 8°, or 10°, or even 12° before it becomes too faint (on one occasion it seemed to appear at 18° elevation), the eastern [anticrepuscular] rays extend more and more toward the west, becoming fainter and fainter and very rarely showing directly overhead. As the pink arch in the east really disappears, 20 to 25 minutes after sunset, a pink glow begins to form in a great area extending from 10° or 15° up to 60° above the western horizon [(*d*) First purple light]. On perfectly clear nights this glow gradually settles toward the horizon [(*c*) First twilight arch] retaining for a long time between it and the horizon a deep lemon-yellow color [(*c*) First bright segment]. About 30 minutes after sunset the lemon-yellow has set [End of civil twilight] and for the next 10, 15, or even 20 minutes the pink glow is gradually disappearing below the western mountains.

When there are a few cirrus clouds at the proper distance to the west of us to cause shadows, the disappearance of the pink arch in the east [(*a*) First anti-twilight arch] with its [anticrepuscular] rays is immediately followed or even accompanied by the formation of a splendid series of bright [crepuscular] rays on the western sky. These are much brighter than those in the east and at first reach an elevation of 40° or more over the place of sunset and a length of 60° or 80°, if low, along the northwestern or southwestern horizon. The base of these rays at first may be 5° or 10° above the horizon, but as the half hour after sunset passes the rays extend from the visible horizon in a deep red color up to 10° or even 20° in altitude. As many as 22 of these bright rays, separated by as many blue shadows, have been counted at one time. A few of the very numerous measurements of elevation have been roughly worked out to get the elevation of the layer or curtain on which these rays and shadows are projected. The process is simple, for the length of time after sunset gives a rough idea of the hundreds of miles of distance between the observer and the clouds which are casting the shadows. This distance is easily shown to be 200 to 400 miles, for some of the best raylike shadows appear 30 minutes after sunset, at which moment the sun is setting at a point some 400 miles west of us. By carrying out this calculation it is easy to show that we are seeing shadows cast upon a layer about 12 miles above the surface of the earth.

As a rule, these shadows appear raylike in form, with the rays diverging from the sun (below the horizon). But occasionally rounded or elongated blue cloud shadows are observed, with direct sunlight, very deep red in color, which has passed underneath the cloud itself, and is projected higher in the western sky than the light which passes over the cloud. The color of these cloud shadows is usually blue but occasionally is a very striking green. [See Abbe's translation of Bezold, p. 622.]

When the pink afterglow [(*d*) First purple light] has sunk low in the west a faint pink glow suffuses the entire horizon [(*e*) Second anti-twilight]. As this second afterglow leaves the east it may be seen as a faint pink glow [(*g*) Second purple light] in the western sky at about an hour after sunset.

The most exquisitely beautiful combination of colors is obtained when there seems to be a long horizontal cloud shadow [(*c*) First twilight arch], cutting through [above] the western afterglow [(*c*) First bright segment] at about 25 minutes after sunset. Under such conditions the lemon-yellow area [(*c*) First bright segment] extends from the horizon perhaps 8° in height through a great part of the western sky, then comes a nearly complete interruption of shadow [(*c*) First twilight arch] above which is the most superb display of a brilliant red band [(*d*) First purple light] extending upwards perhaps 10° or more and divided into glowing [crepuscular] rays all pointing toward the sun, long since out of sight. The color of this pure red glow [(*d*) First purple light] is almost monochromatic and seems much like the color of prominences observed through the C line of hydrogen. It is so different in the splendor of its beauty from the pink edging to the afterglow seen on clear nights that it has become evident that special conditions are required to produce it at its best. And when seen at its best it forms one of the most remarkable meteorological displays ever witnessed by the writer.

TWILIGHT COLORS AT MOUNT WILSON, CAL., AUGUST-SEPTEMBER, 1916.

By WENDELL P. HOGE, Assistant Astronomer.

[Dated: Mount Wilson Solar Observatory, Cal., Nov. 1, 1916.]

[Mr. Ford A. Carpenter, Meteorologist, Weather Bureau, Los Angeles, Cal., transmits the following description of twilight colors observed at the Mount Wilson observatory, contributed by Mr. W. P. Hoge.]

In reference to red sunsets my "log book" contains the following note under date of August 4, 1916: "Very brilliant sunsets for several evenings." This indicates that these brilliant displays began about August 1. Their onset was rather sudden and they have slowly diminished in brightness, although they were quite marked during all of August. The effect is still very noticeable [November 1], particularly in the morning [when] I have a good sky line from 25 to 100 miles distant. The display is gradually growing fainter.

At early dawn a band of crimson [(*f*) Second bright segment], extending some 4° or 5° up from the horizon, appears rather suddenly. This band widens a little and changes rapidly to a deep orange, with decided yellowish green higher up. On several occasions green and orange streamers [crepuscular rays] were sent up, much resembling the aurora as I have seen it *pictured*. It then changes to a lighter yellow; and a little later a very delicate pink, shading into violet [(*d*) First purple light] comes in above it at an altitude of about 25° or 30°. The changes are all very rapid, and frequently it is a very beautiful sight. Earlier, when at its maximum brilliancy, there were indications of streaks of velvety clouds that gave one the impression of a canopy of color spread overhead far to the east, although the sky directly overhead appeared to be entirely free from clouds [Compare Douglass' "soft etching," p. 625].

Whatever the cause of these phenomena it gave us here at Mount Wilson the most wonderfully brilliant sunset and sunrise effects I have ever witnessed.

SOLAR HALO OF SEPTEMBER 28, 1916, AT MIAMI, FLA.

By RICHARD W. GRAY, Meteorologist.

[Dated: Weather Bureau office, Miami, Fla., Oct. 5, 1916.]

A solar halo that developed several progressive and interesting phases was observed at Miami, Fla., on the morning of September 28, 1916. The most important of these phases is shown in the accompanying drawing, which is reproduced from the original sketches made at the time of observation. As no instruments were available for making accurate measurements, the solar distances given and the sun's altitude are estimates, and are, therefore, liable to error. Errors in the estimates of

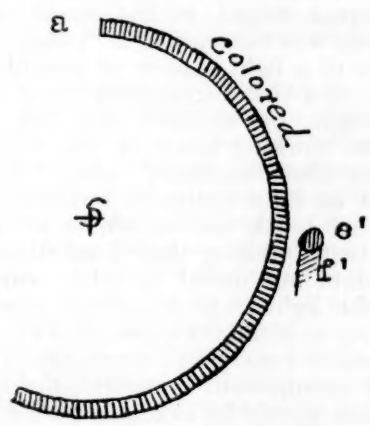

FIG. 1. Solar halo fragment seen at Miami, Fla., Sept. 28, 1916, 7:44 a. m., 90th M. time. *a*, arc of the 22°-halo; *e'*, parhelion of 22°; *f'*, Lowitz' arc(?).

the sun's altitude, however, can be corrected by computing the true altitudes from the time given and the latitude of Miami.

The phenomenon was first seen at 6:46 a. m., 90th meridian time, and at that time about 180° of the upper part of the halo of 22° was visible. To the left of the halo, and slightly above the altitude of the sun, there was a brightly colored arc, probably 5° in length, which strongly impressed the writer as being convex to the sun. The position of this arc relative to the halo and its solar distance (estimated between 35° and 40°) would seem to indicate, however, that the apparent convexity was an illusion and that the colored band was in reality a small segment of the tangent arc of the halo of 22°. The altitude of the sun at this phase of the halo was estimated at 18°.

At 7:07 a. m. the small arc to the left of the halo had disappeared and two parhelia had developed on the circumference of the halo. A rather poorly defined band of white light extended several degrees outward from the parhelion on the right of the sun, this undoubtedly being a fragment of the parhelic circle. The altitude of the sun at this time was probably 20°.

As the sun's altitude increased, the parhelia gradually separated from the halo's circumference, and by 7:40 a. m. they were well without the circle. At 7:44 a. m. (fig. 1) only the parhelion to the right of the sun was visible, and this parhelion had taken on an elongated form of 3° or 4° in extent. Both the parhelion and the band extending downward from it were brightly colored. The phenomenon was closely watched to see whether the band could be identified as a Lowitz arc, but it failed to show any appreciable curvature. This phase continued for about 20 minutes, the sun's altitude at the time being about 26°, The parhelia were visible at intervals to about 8:15 a. m.. and fragments of the halo were seen as late as 9:05 a. m.

METRIC SYSTEM FOR AERONAUTICS.

At the regular monthly meeting of the executive committee of the National Advisory Committee for Aeronautics, held December 7, 1916, the executive committee adopted the metric system as its standard so far as the committee is concerned, and recommendations will be sent to the various departments of the Government that this system be adopted in connection with all matters pertaining to aeronautics.

It is announced that the War Department will put this change into effect immediately in its Aviation Section, using both the metric and the English systems on all drawings for a time.

It is of interest to note in this connection that the upper-air meteorological observations carried on by the Weather Bureau, employed the metric system of units for all its work as early as 1908. The results secured in 1898 were published in English units, those for 1908 onward were published in metric units, beginning with the first issue of the Bulletin of the Mount Weather Observatory for August, 1908. The latest of the bureau's publications in this field, Supplements numbers 3 and 5 to the MONTHLY WEATHER REVIEW, adhere to this practice.

MEASUREMENT OF HORIZONTAL AND VERTICAL MOVEMENT IN THE ATMOSPHERE.[1]

By M. TENANI.

[*Reprinted from* Science Abstracts, Sect. A, Sept. 28, 1916, §989.]

A small captive balloon is employed. The curve of the cord is assumed to be a catenary. The problem then is—Given (1) the weight of the cord per unit of length, (2) the tension at the lower end of the cord (measured by a dynamometer), and (3) the angle made with the horizontal by the lower end of the cord, find (*a*) the tension at the upper end of the cord and (*b*) its direction. These, with the known ascensional force of the balloon, enable the required air-current data to be computed.—*A.* [*Daniell*].

[1] Nuovo cimento, Jan.–Feb., 1916, 11:87–94.

SECTION II.—GENERAL METEOROLOGY.

DAYTIME AND NIGHTTIME PRECIPITATION AND THEIR ECONOMIC SIGNIFICANCE.

By JOSEPH BURTON KINCER.

[Dated U. S. Weather Bureau, Washington, D. C., Nov. 16, 1916.]

In meteorological studies and investigations the subject of diurnal distribution of precipitation for different portions of the United States has heretofore received little attention, although Mr. E. D. Coberly [1] has shown that at New Orleans, La., for the summer months the percentage of day rains, as compared with those occurring at night, range from 75 to 85. Mr. W. P. Stuart,[2] also, points out in the same publication some peculiarities of convectional summer rains at Galveston, Texas, which it appears occur more frequently at night, and mostly during the latter part of the night. While little attention has been given the subject in this country, a considerable amount of information on the diurnal march of rainfall in different parts of the world is given in Hann's Lehrbuch der Meteorologie, 3d ed., pages 338–346; also in Aus dem Archiv der Deutschen Seewarte, volume 18, 1895, No. 3. The information on the subject contained in these publications seems to establish a more or less general continental type of maximum rainfall during the warm hours of the day and an opposite coast type of maximum night rains, although a number of exceptions to this general rule are pointed out.

The concentration of precipitation about certain hours of the day is not only interesting from a scientific viewpoint, but has an important economic value as well. As touching the former, if in some sections of the country by far the greater portion of the total rainfall occurs during the daylight hours, while in others the reverse is true and and the greater amount occurs at night, the question as to the cause of such distribution, whether resulting from widely applicable atmospheric laws or from local geographic or topographic conditions, at once presents itself. Again, it is of interest to the forecasters of the Weather Bureau, as considered from the viewpoint of probability. If, for example, in a given locality during certain periods of the year daytime rains occur more frequently—say, in the ratio of 2 to 1—while in other sections night rains are of more frequent occurrence, that fact should have due weight in forecasting for the respective day and night periods, especially when unsettled conditions with a probability of showers obtain.

The economic side of the subject when applied to the country as a whole must be considered of great importance, especially in connection with agricultural enterprises. By far the greater portion of the activities of mankind is conducted in the open air and during the daylight hours, and while rainfall is indispensable, there is necessarily a loss of more or less time as a result of rainy weather during the working hours of the day. As the frequency and duration of rainfall vary widely for different sections of the country, there is a proportionate variation in the resulting loss of time. If in some localities, for example, this amounts to, say, 50 per cent more than in others, the question becomes of great economic importance, affecting, as it does, the earning capacity of thousands of men. In the planning of any extensive outdoor work this question of loss of time must be taken into account, and obviously a knowledge of its probable amount is necessary for an intelligent consideration of the subject.

Agricultural enterprises constitute the most extensive outdoor activity and consequently the farmers are more concerned than any other class; it is often of considerable importance to them whether rain falls during the working hours of the day, or during the night. Furthermore, other things being equal, a farmer operating in a section of the country where the average number of working hours lost is much greater than in some other section, is obviously at a material disadvantage in competition with his neighbor in the more favored district, especially when the employment of labor is on a monthly basis of compensation.

Much information is available in Weather Bureau publications showing the average amount and the important characteristics of rainfall for different localities. Among this material are statistics tabulated in convenient form for reference and for comparing one section with another, showing the average monthly number of days, midnight to midnight, on which rain to the amount of 0.01 inch or more occurs. However, these latter values have their limitations for the purpose of considering the question of actual duration of rainfall as affecting working conditions, for the reason that all days on which rain fell were given equal weight in the count, regardless of whether the day was denominated "rainy" by reason of the occurrence of a light shower of possibly a few minutes' duration, and that perhaps occurring at some time during the night, or whether rain fell continuously throughout the working hours of the day. It will be seen that a day thus designated "rainy" may be one on which little or no interruption to outdoor work results, or, on the other hand, one on which no such work is possible. Notwithstanding their limitations in this respect, these data are useful in other connections and throw a valuable light on an important climatic factor.

In considering in detail the question of rainfall duration from an economic standpoint, especially when it is desired to make comparisons between different sections of the country, data should be available for a sufficient number of representative stations to indicate general conditions, showing for each month the average actual duration of rainfall during the working hours of the day. Such compilations for the entire country, covering a sufficient period of time to give reliable and comparable results, would, however, involve a vast amount of work and a cost that can not be undertaken at this time.

The accompanying charts and diagrams, covering the period from April to September, inclusive, have been prepared as an aid in pointing out in a general way the variations in the diurnal distribution of rainfall for the different sections of the country. They bring out in this respect for different regions, certain pronounced characteristic features which have not heretofore been recognized.

[1] *See* MONTHLY WEATHER REVIEW, 1914, 42: 537.
[2] Ibidem, 1913, 41: 1225.

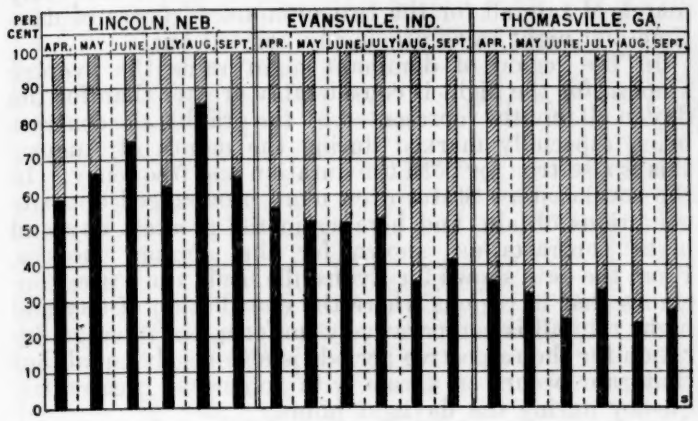

FIG. 1. Percentages of the total *rainfall* occurring at night (7P to 7A) and during the day (7A to 7P) for the months and at the localities indicated, for the 10 years 1906 to 1915. Heavily shaded portions indicate nocturnal percentages. (Standard time in local use.)

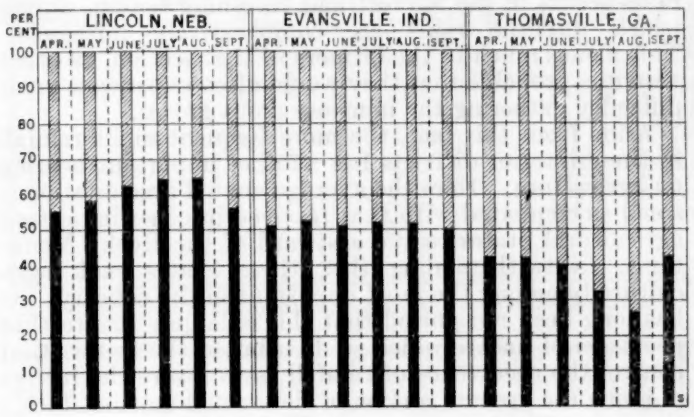

FIG. 2. Percentages of total *duration* of rain occurring at night (7P to 7A, heavy shading) and during the day (7A to 7P), for the months and at the localities indicated, for the 10 years 1906 to 1915.

By referring to these illustrations it will be seen that wide variations as to the occurrence of rainfall during the day and night obtain for different sections of the United States. The chart forming figure 8 shows the average amount of precipitation that occurs during the daytime,[3] for the period April to September, inclusive. Figure 9 shows the average amounts occurring at night for the same months, while figure 10 shows the percentage occurring at night. These charts are based on the records of about 175 regular Weather Bureau stations, well distributed throughout the country, for the 20-year period 1895 to 1914, inclusive. The most important feature of these charts is their indication of the large variations in the occurrence of night and day rains over the country east of the Rocky Mountains. The statistical basis for this portion of the charts is therefore given in detail by Table 4. From the Rocky Mountains westward the variations are not specially marked, nor is the question of so much significance, as summer rainfall in those districts is generally light and even negligible over considerable areas.

The outstanding features of figure 8 are the concentration of daytime rainfall in the Southeastern States, where falls of more than 20 inches are shown, and the regularity of the progressive decrease to the northward and westward. On figure 9, showing night rainfall, the concentration shifts to the Central Plains States, where falls of 12 to 15 inches are shown, and from this region there likewise appears a regular and progressive decrease in all directions. These contrasts are brought out graphically on a percentage basis in figure 10, which shows that for portions of the Southeastern States only about 25 per cent of the total fall occurs at night, while in the Central Plains districts from 60 to 65 per cent, or more, occurs during that time. The number and length of the records used in the preparation of these charts and their uniform and comparable indications insure that they are representative of actual conditions.

[3] The terms "day" and "night" as used in this paper, unless otherwise indicated, have reference to the period from 8 a. m. to 8 p. m., and from 8 p. m. to 8 a. m., respectively, *75th meridian time*, the division points corresponding to the hours of the regular twice-daily observations at the regular Weather Bureau stations.

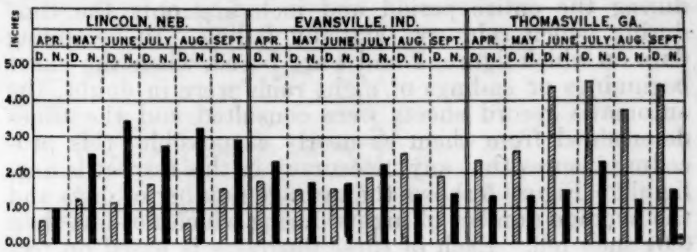

FIG. 3. Average *amount of rain* that fell during the day (7A to 7P)and during the night, (7P to 7A, heavy shaded columns), for the months and at the places shown, for the 10 years 1906 to 1915.

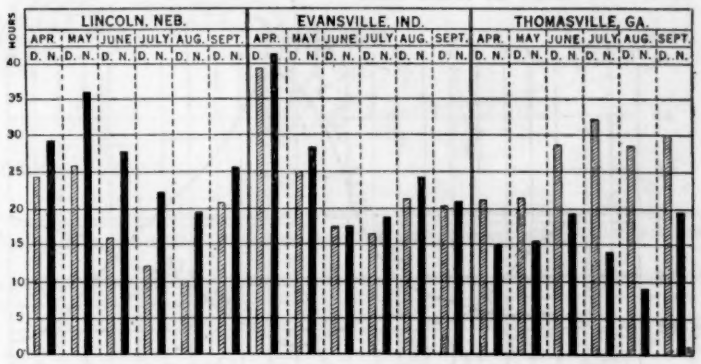

FIG. 4. Average number of hours by night (7P to 7A) and by day (7A to 7P) during which rain fell in the months and at the places indicated, for the 10 years 1906 to 1915.

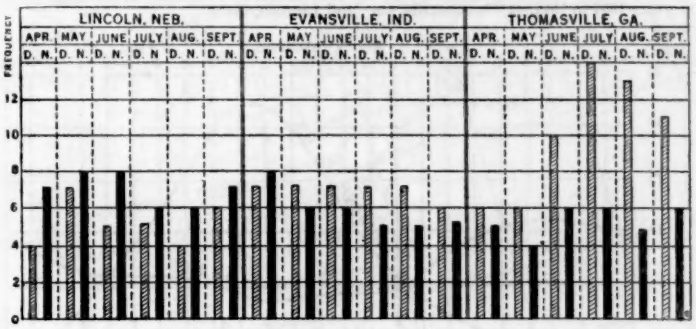

FIG. 5. The average number of days and of nights during which rain to the amount of 0.01 inch or more, fell in the months and at the places indicated, for the 10 years 1906 to 1915.

The charts just referred to show in a general way the distribution of day and night rains, but for application in detail to economic questions one needs to know the actual duration of rainfall during the working hours of the day, and it is regretted that it is not possible at this time to make a general survey of rainfall duration for all sections of the country, based on local mean time. However, these details are shown for three representative stations in figures 1 to 7. Lincoln, Nebr., is more or less representative of the area in which night rains predominate; Thomasville, Ga., of the opposite conditions, and Evansville, Ind., of the regions in which the day and night rains are more or less equal, both in amount and actual duration.

Tables 1, 2, and 3 show the amounts, duration, and frequency of daytime and nighttime rainfall for each of these points for the months of April to September, inclu-

sive, for the 10-year period 1906–1915. The corresponding average values for the same periods are graphically presented in figures 1 to 5.

Figure 1 shows the percentages of the total rainfall occurring at night and during the day, and figure 2 indicates similar values for rainfall duration. Figure 3 shows the average amounts for the respective day and night periods, while figure 4 shows the average duration by day and by night. These latter values were computed by charting the beginning and the ending of each rain during the entire period and including only the time during which rain was actually falling. In compiling data on which figures 2 and 4 are based, when the exact beginnings or endings of night rains were in doubt, the automatic record sheets were consulted and the times determined from them as nearly as possible; this procedure insures that any inaccuracy in this respect is negligible. Figure 5 shows the average number of days and the average number of nights during which not less than 0.01 inch fell. Each of these diagrams is based on records covering the uniform 10-year period 1906–1915, the day and night division hours (7ª and 7ᵖ) being on standard time in local use.

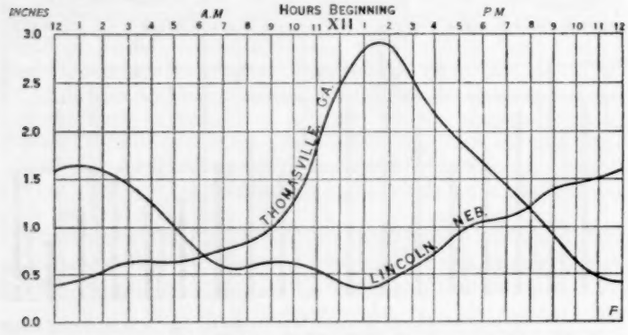

FIG. 6. The average hourly rainfall for the season, April to September, incl., for the 10 years 1906 to 1915, at Thomasville, Ga., and Lincoln, Nebr.

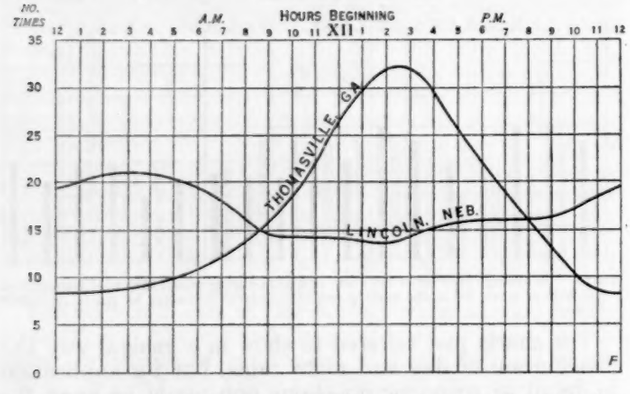

FIG. 7. The average hourly frequency of rainfall for the season, April to September, incl., for the years 1906 to 1915, at Thomasville, Ga., and Lincoln, Nebr.

Figure 6 shows for Lincoln, Nebr., and Thomasville, Ga., the diurnal march of rainfall as indicated by the average hourly amounts, local mean time, for the 6-month period, April to September, inclusive, while figure 7 shows for the same stations and period the average frequency of rainfall. Figure 6 is based on the average amount of precipitation recorded for each hour of the day for the entire six months and figure 7 on the average number of times rain occurred during the respective hours; both are compiled for the 10-year period 1906–1915. Owing to the short interval of time for which the data are compiled (one hour) the results are shown by a curve, smoothed by the simple formula $(a+2b+c)/4$. These graphs clearly indicate the characteristics of the daily march of rainfall for the two pronounced types of daytime and night rains previously pointed out.

In the region of dominant night rains the average amount for the night is considerably greater than for the day in all months represented by the graphs, the contrast being especially marked during the month of August; this is also true for both the duration and frequency. In the southeastern States even more pronounced opposite conditions obtain, and here again the greatest day and night contrasts are shown for the summer months. From the data shown for Evansville, Ind., the writer concludes that in regions where the distribution of day and night rainfall is comparatively uniform, the average duration for the respective periods is also nearly equal, but that rain occurs as a rule with somewhat greater frequency during the daylight hours.

In the Central Plains region, where farming is conducted on a large scale and where wheat is the principal product, we find that the greatest concentration of night rains occurs in the harvest and threshing season, during which daytime rains are comparatively infrequent. This means much to the farmers of that section, as otherwise it is probable that they would often experience great difficulty gathering the immense crops grown.

Aside from this fact, the more frequent night rainfall in these interior districts has another important bearing on agriculture. Here the average annual precipitation is small as compared with that received in other important agricultural States to the eastward of the Rocky Mountains. Notwithstanding this, these States rank agriculturally among the most important in the country. It has long been recognized that this is largely due to that provision of nature which so distributed the factors that control the occurrence of rainfall as to insure the receipt of much the greater portion of the annual amount during the warm or growing season. Had the distribution been uniform throughout the year as in the more eastern districts, these fertile plains would have been a barren waste. In addition to this we now find that another happy provision has been made in that the greater portion of the warm-season rainfall occurs during the night; that is, at a time when it will do the maximum amount of good.

Summer rains in the United States occur largely in the form of thundershowers; droughts of more or less intensity are of rather frequent occurrence especially in the Plains States, and are usually accompanied by high temperatures. During such periods the amount of benefit to vegetation brought by showers of small or moderate amounts depends very largely on the time of occurrence, whether in the heated hours of the day or the relatively cool night. After a daytime shower the hot sunshine usually causes rapid evaporation and crusts the cultivated soil, so that little or no benefit and often actual harm results. When the summer showers occur at night, the moisture penetrates the soil to a much greater depth, little evaporation occurs, usually crusts are not formed, and a maximum of benefit results. In the Southeastern States, where the summer rainfall is usually abundant, the question of diurnal distribution so far as its bearing on the development of vegetation is concerned, is not of so great importance.

The dominance of daytime rains in the Southeast and along the immediate Gulf coast is undoubtedly due to atmospheric convection during the warmer portions of the day, a characteristic of tropical and semitropical rainfall conditions, but just why there should be so well-defined an area and so pronounced a type of night rainfall in the Central Plains region, with a progressive diminution in all directions, is not readily apparent.

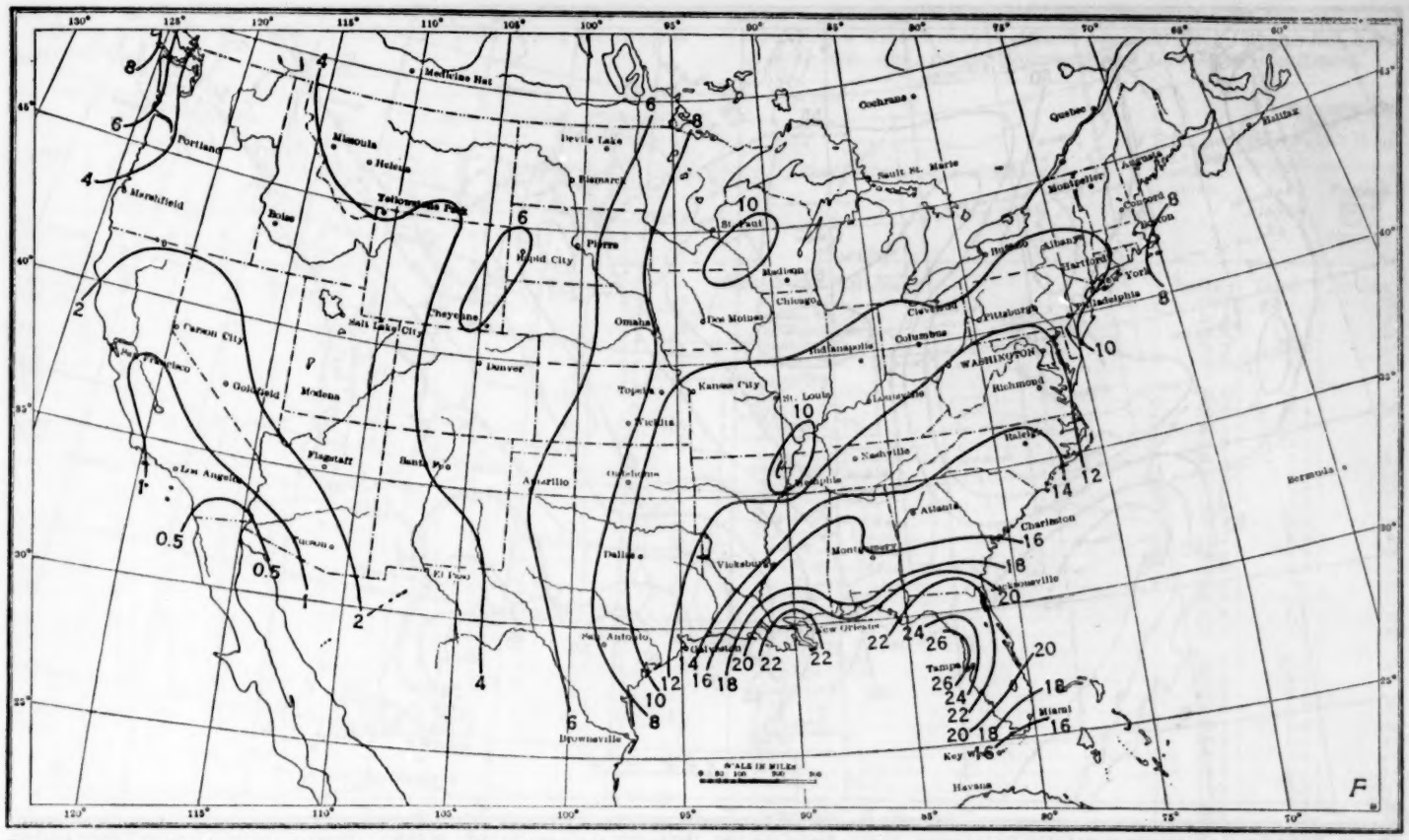

FIG. 8. Average precipitation in inches, during the day (8ᴬ to 8ᴾ) for the season, April to September, incl., 1895 to 1914. (Based on about 175 Weather Bureau stations, and 75th M. time.

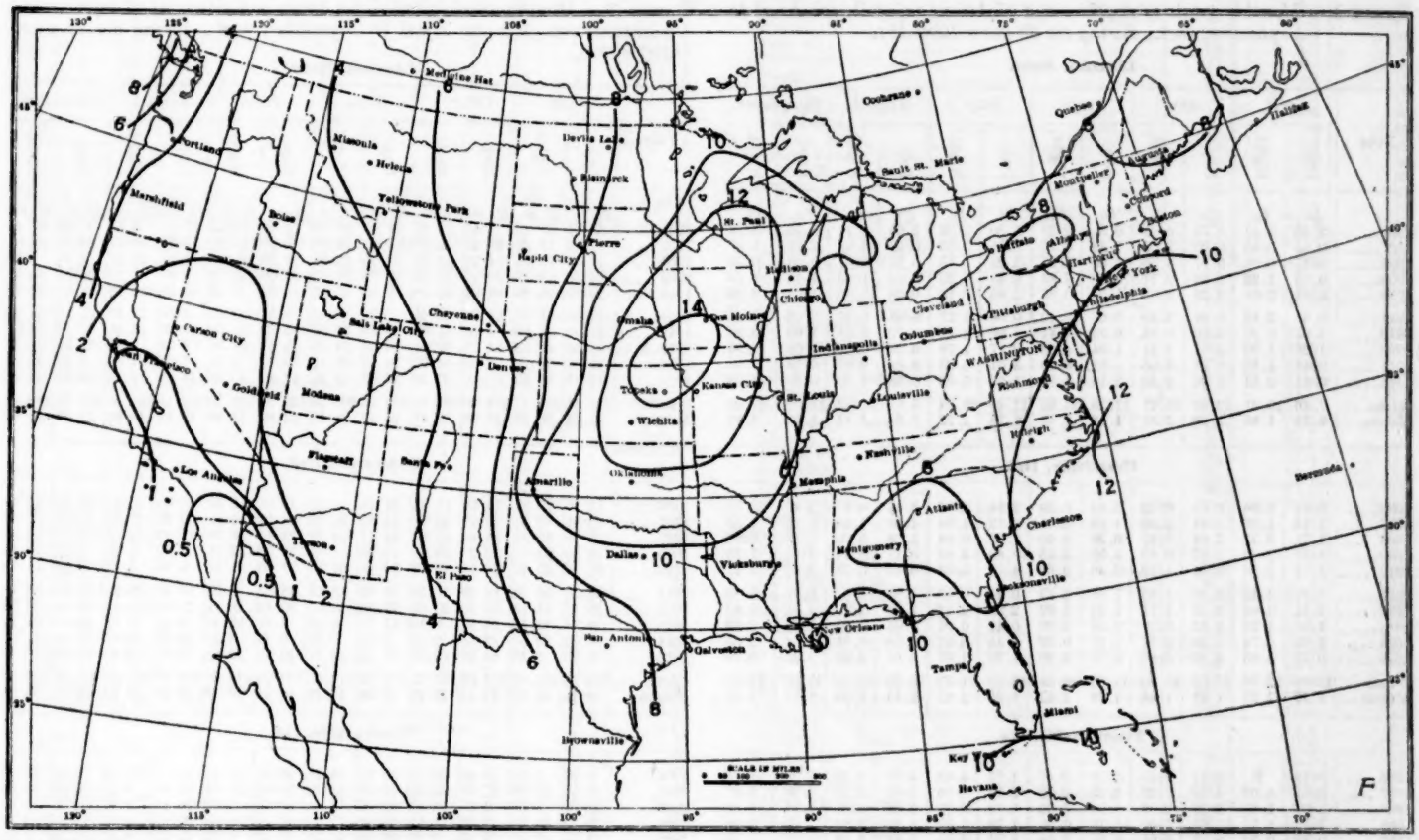

FIG. 9. Average precipitation in inches, during the night (8ᴾ to 8ᴬ) for the season, April to September, incl., 1895 to 1914. (Based on about 175 Weather Bureau stations, and 75th M. time.)

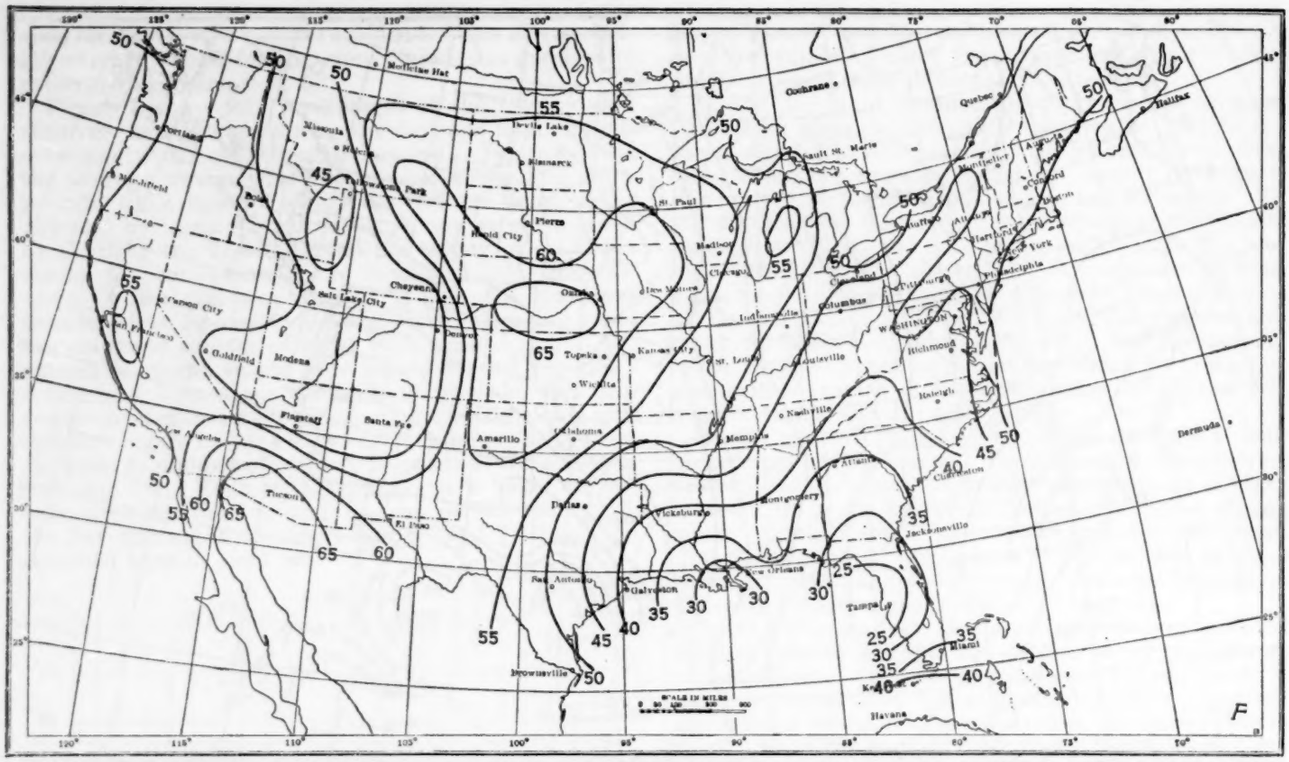

FIG. 10. Percentage of the average precipitation for the season, April to September, incl., 1895 to 1914, that occurs at night (8P to 8A). (Based on about 175 Weather Bureau stations, and 75th M. time.)

TABLE 1.—*Monthly totals of daytime and nighttime rainfalls for April to September, incl., during the 10 years 1906–1915.*

Lincoln, Nebr.

Year.	April.		May.		June.		July.		August.		September.	
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1906.....	2.23	1.19	0.71	0.91	0.81	2.31	5.30	2.03	2.60	0.14	5.36	2.24
1907.....	0.55	0.46	0.60	2.59	1.49	4.76	0.11	3.55	0.25	3.92	2.27	1.67
1908.....	0.37	0.91	0.77	3.56	2.03	9.21	2.25	5.83	0.21	2.61	0.23	0.30
1909.....	0.10	1.22	3.44	2.11	0.29	2.87	0.48	4.39	0.04	1.20	1.40	3.29
1910.....	0.01	0.01	2.28	1.33	1.24	0.85	2.85	0.18	0.35	13.86	1.98	3.08
1911.....	0.35	2.12	0.58	3.46	0.07	0.49	0.06	1.77	0.05	0.27	0.95	3.71
1912.....	1.67	0.70	0.10	0.84	0.73	2.41	1.06	1.12	0.72	3.39	1.09	2.00
1913.....	1.26	1.20	2.91	3.11	1.04	1.23	0.17	1.78	0.15	0.16	1.06	2.24
1914.....	0.48	1.86	0.14	4.06	1.91	8.80	3.61	1.23	0.58	0.89	0.88	7.44
1915.....	0.44	0.84	1.36	3.50	2.18	1.72	1.57	5.30	0.68	4.89	0.83	3.09
Sums....	7.46	10.51	12.89	25.47	11.79	34.65	17.46	27.18	5.63	31.33	16.05	29.06
Means...	**0.75**	**1.05**	**1.29**	**2.55**	**1.18**	**3.46**	**1.75**	**2.72**	**0.56**	**3.13**	**1.60**	**2.91**

Evansville, Ind.

1906.....	0.71	0.96	0.75	0.32	2.43	0.59	2.84	2.37	3.44	0.95	3.46	0.70
1907.....	1.14	1.29	1.84	2.05	1.98	2.31	2.72	1.94	4.69	1.26	1.23	1.53
1908.....	1.71	3.23	2.64	3.87	0.26	0.40	1.79	0.18	3.68	0.90	0.28	0.95
1909.....	1.39	3.82	1.87	0.60	1.08	2.13	0.89	4.84	0.17	0.24	1.11	1.19
1910.....	1.71	2.58	0.91	1.72	0.46	2.66	4.73	5.59	0.43	0.53	2.22	1.17
1911.....	4.21	4.15	0.70	1.63	1.88	2.42	0.44	0.42	1.85	3.07	2.37	0.88
1912.....	2.41	4.61	2.13	1.71	1.44	1.92	2.98	2.32	1.70	2.30	1.81	0.83
1913.....	1.96	1.23	0.32	0.27	0.96	0.59	0.41	0.94	1.05	0.69	1.69	2.62
1914.....	2.09	0.74	0.26	0.77	3.67	0.32	0.44	0.97	2.68	0.91	2.51	2.55
1915.....	0.35	0.05	4.10	3.86	0.79	2.90	1.26	1.65	5.64	2.20	2.20	0.78
Sums....	17.68	22.66	15.52	16.80	14.95	16.24	18.50	21.22	25.33	13.05	18.88	13.20
Means...	**1.77**	**2.27**	**1.55**	**1.68**	**1.50**	**1.62**	**1.85**	**2.12**	**2.53**	**1.30**	**1.89**	**1.32**

Thomasville, Ga.

1906.....	0.18	T.	4.51	1.57	2.76	0.47	4.73	4.03	4.53	2.98	7.28	2.18
1907.....	3.02	4.02	4.80	1.27	2.23	2.35	2.89	5.98	3.07	1.55	6.98	1.67
1908.....	3.01	1.61	1.22	2.69	1.94	1.06	6.70	0.70	2.98	0.05	2.94	1.30
1909.....	3.55	1.17	1.37	0.66	10.18	0.90	4.73	1.73	6.12	0.84	5.09	0.98
1910.....	0.80	0.92	2.34	0.01	8.01	2.08	4.34	2.30	3.94	0.68	2.41	0.14
1911.....	3.06	0.34	3.06	0.34	4.08	0.22	6.94	0.67	2.56	1.31	2.50	0.02
1912.....	7.42	2.91	2.03	0.09	3.04	3.57	4.84	0.50	5.60	1.52	6.45	3.97
1913.....	0.50	0.88	1.63	0.97	4.95	3.22	1.96	2.82	2.18	1.58	1.67	0.63
1914.....	1.53	0.25	1.27	0.18	2.10	0.30	3.40	3.02	3.84	0.12	4.44	3.14
1915.....	0.08	0.49	3.99	4.76	3.81	0.34	4.05	0.63	2.50	0.26	3.96	0.45
Sums....	23.15	12.59	26.22	12.54	43.10	14.51	44.58	22.38	37.32	10.89	43.72	14.48
Means...	**2.32**	**1.26**	**2.62**	**1.25**	**4.31**	**1.45**	**4.46**	**2.24**	**3.73**	**1.09**	**4.37**	**1.45**

TABLE 2.—*Monthly total duration (in hours and minutes) of daytime and nighttime rainfalls for April to September, incl., during the 10 years 1906–1915.*

Lincoln, Nebr.

Years.	April.		May.		June.		July.		August.		September.	
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.
	H. m.	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*	*H. m.*
1906.....	33 52	37 10	7 47	15 55	11 05	21 19	15 40	13 15	13 07	5 47	26 23	17 42
1907.....	22 33	19 23	27 43	34 50	19 50	29 30	9 27	15 03	10 36	14 18	22 07	22 01
1908.....	16 33	15 15	34 15	45 12	27 06	62 51	19 56	24 05	11 41	24 55	9 35	7 20
1909.....	24 20	42 26	20 17	32 10	11 38	26 07	22 00	50 52	2 09	7 00	29 13	45 54
1910.....	20 20	25 25	44 03	40 46	9 15	12 15	9 37	7 22	16 23	32 19	17 51	21 25
1911.....	20 51	37 07	18 24	26 46	2 37	2 04	3 51	14 25	3 50	18 30	21 16	33 22
1912.....	21 05	11 18	4 00	31 03	25 06	33 20	5 48	21 30	20 39	24 01	31 46	36 07
1913.....	48 50	55 15	34 01	59 03	5 54	24 29	5 21	24 35	2 42	5 45	21 52	24 39
1914.....	15 06	24 29	8 59	14 33	14 43	28 12	10 46	4 14	7 08	22 00	9 23	25 18
1915.....	12 15	16 59	62 00	57 56	30 09	25 26	17 42	45 29	14 03	37 21	20 58	28 28
Sums....	235 45	284 47	261 29	358 14	157 23	265 33	120 08	220 50	102 18	191 56	210 24	262 16
Means...	**23 34**	**28 29**	**26 09**	**35 49**	**15 44**	**26 33**	**12 00**	**22 00**	**10 14**	**19 10**	**21 00**	**26 14**

Evansville, Ind.

1906.....	18 54	15 39	12 58	10 05	21 44	14 11	22 07	19 50	30 58	13 32	52 50	42 40
1907.....	35 35	48 50	29 35	42 10	14 32	16 32	13 53	10 43	30 25	27 23	13 50	20 07
1908.....	45 48	59 39	25 49	36 07	15 17	10 52	23 14	20 06	11 49	19 35	6 47	12 30
1909.....	14 00	35 27	36 27	38 35	18 25	31 05	14 58	22 33	3 49	3 20	7 58	16 14
1910.....	65 12	65 57	34 25	46 08	15 43	27 05	27 36	31 57	9 46	8 27	12 58	14 25
1911.....	50 24	56 29	14 29	16 55	21 01	19 15	18 16	6 58	14 04	30 20	17 18	28 40
1912.....	38 46	61 13	31 20	23 01	23 00	20 10	20 42	18 17	25 46	23 14	15 01	20 30
1913.....	56 14	36 10	16 31	6 10	11 58	6 13	6 01	19 47	8 20	10 43	36 41	29 18
1914.....	50 12	29 04	7 05	2 10	7 54	8 59	6 27	8 58	32 03	37 31	18 49	11 09
1915.....	17 35	5 35	44 29	62 00	21 16	19 41	10 14	20 45	46 30	63 40	21 25	10 45
Sums....	392 40	414 03	253 08	283 21	170 50	174 03	163 28	179 54	213 30	237 45	203 37	206 18
Means...	**39 16**	**41 24**	**25 19**	**28 20**	**17 00**	**17 24**	**16 21**	**17 59**	**21 21**	**23 46**	**20 22**	**20 38**

Thomasville, Ga.

1906.....	1 54	0 10	39 45	30 36	32 50	24 27	30 57	17 28	34 15	20 00	26 06	17 20
1907.....	41 13	55 58	32 58	23 36	15 20	13 40	39 06	37 35	35 04	6 25	50 08	34 06
1908.....	26 39	8 09	9 05	15 57	10 57	5 44	39 06	5 58	26 19	3 35	28 44	36 09
1909.....	33 14	21 03	19 03	18 51	33 42	11 45	42 22	36 04	22 49	12 13	18 00	4 27
1910.....	11 45	9 52	12 40	2 22	60 49	48 59	28 06	4 35	19 58	6 03	12 35	5 20
1911.....	14 53	8 10	24 56	7 38	25 05	8 23	42 17	9 03	27 08	6 08	10 15	2 23
1912.....	40 32	22 00	10 35	7 11	49 44	43 14	33 02	5 07	33 01	13 25	53 05	49 14
1913.....	16 03	11 22	17 58	20 44	21 22	11 48	20 18	6 54	20 47	17 27	24 25	13 27
1914.....	9 26	2 41	6 51	2 16	12 44	13 57	21 19	14 56	36 58	4 39	48 55	2 34
1915.....	11 43	11 20	36 31	25 49	14 58	4 13	20 07	6 13	20 59	2 20	26 25	23 20
Sums....	207 22	150 45	210 22	155 00	277 31	186 10	316 40	143 53	277 18	92 15	298 38	188 20
Means...	**20 44**	**15 00**	**21 00**	**15 30**	**27 45**	**18 37**	**31 40**	**14 23**	**27 44**	**9 14**	**29 52**	**18 50**

TABLE 3.—*Monthly numbers of days and of nights on which 0.01 inch or more of rain fell, from April to September, incl., during the 10 years 1906–1915.*

Lincoln, Nebr.

Years.	April.		May.		June.		July.		August.		September.	
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.
1906	8	9	5	6	5	6	8	6	7	4	8	6
1907	3	5	9	7	5	11	2	7	3	6	5	7
1908	4	8	9	15	9	15	7	5	7	11	2	1
1909	2	8	7	7	3	6	5	8	2	2	7	10
1910	1	1	9	9	4	4	5	2	4	7	3	6
1911	5	9	5	8	2	4	1	3	3	7	4	5
1912	4	5	2	6	8	7	3	6	7	5	9	11
1913	7	7	9	8	1	8	3	6	2	2	6	7
1914	3	7	2	5	5	13	5	4	3	6	7	5
1915	6	7	11	11	8	7	9	12	6	10	6	8
Sums	43	66	68	82	50	81	48	59	44	60	57	66
Means	**4**	**7**	**7**	**8**	**5**	**8**	**5**	**6**	**4**	**6**	**6**	**7**

Evansville, Ind.

1906	4	4	5	5	8	6	8	4	8	5	10	7
1907	5	9	9	9	7	6	7	5	10	6	6	6
1908	8	12	7	7	5	5	8	4	4	4	1	1
1909	4	8	10	7	8	11	6	5	3	2	4	6
1910	11	13	9	7	5	4	11	10	5	3	5	4
1911	11	10	4	4	7	5	5	4	6	5	7	8
1912	9	9	7	8	7	3	11	7	10	9	3	4
1913	8	7	4	3	5	3	2	4	4	4	9	7
1914	7	6	2	2	8	2	3	2	9	6	4	4
1915	4	2	14	12	7	10	6	7	15	8	6	3
Sums	71	80	71	64	67	55	67	52	74	52	55	50
Means	**7**	**8**	**7**	**6**	**7**	**6**	**7**	**5**	**7**	**5**	**6**	**5**

Thomasville, Ga.

1906	1	0	8	5	9	4	16	9	16	10	9	4
1907	10	11	6	3	7	5	15	6	15	5	15	12
1908	7	6	3	3	9	4	16	5	11	3	10	7
1909	10	8	8	5	10	4	16	7	12	5	7	5
1910	4	5	6	1	16	10	18	3	11	6	6	2
1911	4	5	8	5	11	5	18	7	15	2	11	1
1912	8	8	5	2	14	9	15	4	14	6	14	11
1913	5	2	5	5	13	8	8	3	11	9	11	4
1914	4	2	4	2	7	6	10	9	15	2	12	6
1915	3	3	10	7	5	2	11	3	12	1	11	3
Sums	56	50	63	38	101	57	143	56	132	49	106	55
Means	**6**	**5**	**6**	**4**	**10**	**6**	**14**	**6**	**13**	**5**	**11**	**6**

TABLE 4.—*Average seasonal total and nighttime (8p to 8a, 75th m.t.) precipitation at Weather Bureau stations east of the Rocky Mountains, April to September, incl., for the 20-year interval 1895–1914.*

[Based on continuous records by the automatically recording raingage.]

Stations (arranged geographically).	Average seasonal totals.	Average nighttime falls (8p to 8a, 75th M. t.).	
		Amount.	Percentage of total seasonal.
Atlantic coast:	*Inches.*	*Inches.*	*Per cent.*
Eastport, Me	16.1	8.0	50
Portland, Me	18.4	8.8	48
Burlington, Vt	16.9	8.3	49
Northfield, Vt	17.7	8.0	45
Boston, Mass	18.4	8.8	48
Hartford, Conn	19.9	9.9	49
New Haven, Conn	21.5	11.0	51
Albany, N. Y	17.2	8.0	46
Ithaca, N. Y	18.4	7.4	40
Binghamton, N. Y	17.4	7.5	43
New York, N. Y	21.0	9.4	45
Scranton, Pa	20.4	9.5	46
Harrisburg, Pa	18.5	8.5	46
Philadelphia, Pa	22.6	10.7	47
Atlantic City, N. J	19.5	10.5	54
Baltimore, Md	22.7	9.1	40
Washington, D. C	23.0	10.2	44
Norfolk, Va	23.9	10.1	42
Richmond, Va	22.7	10.0	44
Lynchburg, Va	22.6	9.8	43
Wytheville, Va	22.1	8.3	37
Asheville, N. C	23.4	9.4	40
Charlotte, N. C	23.6	9.6	41
Raleigh, N. C	26.4	10.8	41
Hatteras, N. C	25.0	13.5	54
Wilmington, N. C	25.7	10.3	40
Charleston, S. C	24.2	10.9	45
Columbia, S. C	25.5	9.6	38
Augusta, Ga	24.5	8.3	34
Atlanta, Ga	22.3	7.8	35
Macon, Ga	21.6	7.8	36
Savannah, Ga	26.8	9.5	35
Thomasville, Ga	31.2	8.9	28
Jacksonville, Fla	30.0	7.7	26
Gulf region:			
Key West, Fla	22.0	10.1	46
Tampa, Fla	35.5	8.4	24
Pensacola, Fla	30.1	12.1	40
Mobile, Ala	34.2	12.5	37
Montgomery, Ala	23.4	7.6	32
Birmingham, Ala	26.3	9.3	35
Meridian, Miss	27.0	9.6	36
Vicksburg, Miss	23.2	9.4	41
New Orleans, La	32.6	8.2	25
Shreveport, La	21.2	8.4	10
Little Rock, Ark	23.4	11.2	48
Fort Worth, Tex	20.0	10.0	50
Taylor, Tex	17.1	7.6	44
Galveston, Tex	23.6	11.1	47
Corpus Christi, Tex	13.8	6.8	49
San Antonio, Tex	15.2	7.0	46
Ohio Valley and Tennessee:			
Memphis, Tenn	19.5	10.1	52
Nashville, Tenn	22.2	9.8	44
Chattanooga, Tenn	22.3	9.4	42
Knoxville, Tenn	23.0	9.7	42
Lexington, Ky	20.7	9.0	43
Louisville, Ky	20.3	9.5	47
Evansville, Ind	20.1	9.8	49
Indianapolis, Ind	20.0	9.7	48
Cincinnati, Ohio	17.5	7.9	45
Columbus, Ohio	17.9	7.6	42
Parkersburg, W. Va	20.2	9.0	45
Elkins, W. Va	27.2	12.6	46
Pittsburg, Pa	19.0	8.5	45
Great Lakes region:			
Oswego, N. Y	17.5	8.8	50
Rochester, N. Y	15.8	7.4	47
Buffalo, N. Y	16.1	8.4	52
Erie, Pa	18.2	9.7	53
Cleveland, Ohio	17.5	8.4	48
Sandusky, Ohio	19.2	8.6	45
Toledo, Ohio	18.4	8.7	47
Detroit, Mich	17.8	8.6	48
Port Huron, Mich	16.1	7.8	48
Alpena, Mich	16.1	7.6	47
Grand Rapids, Mich	19.9	11.8	59
Grand Haven, Mich	17.7	10.4	59
Chicago, Ill	18.7	9.9	53
Milwaukee, Wis	17.7	9.6	54
Green Bay, Wis	20.2	11.1	55
Escanaba, Mich	18.7	9.3	50
Sault Ste. Marie, Mich	16.4	8.3	51
Marquette, Mich	17.9	8.8	49
Houghton, Mich	17.9	9.3	52
Duluth, Minn	19.5	10.6	54
Upper Mississippi Valley:			
St. Paul, Minn	21.0	12.5	60
La Crosse, Wis	22.1	12.0	54
Madison, Wis	20.4	11.3	55
Charles City, Iowa	22.7	12.5	56
Dubuque, Iowa	21.1	12.8	61
Davenport, Iowa	20.1	11.3	56
Des Moines, Iowa	22.9	13.8	60
Keokuk, Iowa	22.2	13.0	58
Peoria, Ill	20.5	11.4	56
Springfield, Ill	20.6	10 9	53
Hannibal, Mo	22.9	12.9	56
St. Louis, Mo	21.0	10.8	51
Cairo, Ill	18.9	9.4	50
Plains region:			
Del Rio, Tex	13.1	7.2	55
Abilene, Tex	16.6	8.9	53
Fort Smith, Ark	21.5	11.4	53
Bentonville, Ark	20.0	12.8	64
Springfield, Mo	25.4	13.0	51
Columbia, Mo	24.0	13.1	55
Kansas City, Mo	25.8	15.4	60
Topeka, Kans	24.1	14.8	61
Iola, Kans	24.8	13.6	55
Wichita, Kans	21.6	13.7	63
Oklahoma, Okla	20.2	11.5	57
Amarillo, Tex	16.5	10.4	63
Dodge City, Kans	15.7	9.6	61
Concordia, Kans	21.0	13.5	64
Lincoln, Nebr	23.3	15.4	66
Omaha, Nebr	20.0	12.5	62
North Platte, Nebr	14.5	9.8	68
Sioux City, Iowa	20.3	12.0	59
Yankton, S. Dak	19.9	11.6	58
Valentine, Nebr	15.0	9.3	62
Rapid City, S. Dak	13.8	7.4	54
Huron, S. Dak	15.7	9.1	58
Bismarck, N. Dak	12.5	7.3	58
Devils Lake, N. Dak	13.3	8.0	60
Williston, N. Dak	11.3	6.4	57
Havre, Mont	9.6	5.1	53

FREQUENCY CURVES OF CLIMATIC PHENOMENA.[1]

By HOWARD ROSS TOLLEY, Scientific Assistant.

[Dated: U. S. Office of Farm Management, Washington, Oct. 24, 1916.]

A person who wishes to attempt farming in a new region, or even one who farms intelligently in a region with which he is acquainted, must have more than a haphazard knowledge of the variability of the climate of the region. He should know how often it will be too wet for one crop or too dry for another; how often the summer will be too cool or too hot; how often the growing season will be too short or the winter too cold. In short, a knowledge of the frequency of unfavorable occurrences of climatic phenomena is necessary for successful agriculture, and inasmuch as this knowledge enters into the determination of what crops are or are not suitable for any given locality, the investigation of the variability of climatic phenomena is a matter of great importance in farm management.

All farmers know that their business is liable to loss on account of unfavorable weather, and most of them have a fair empirical knowledge of the amount of risk to which their crops are subject. To the man with only a small capital, the loss of a single staple crop will often be disastrous, and the unsuccessful farmer can often trace his failure to injurious weather. Of course, this hazard can not be controlled, but a knowledge of the ways in which climatic phenomena occur in general, and an investigation of the records for a particular locality will render it possible at least to reduce the risk of such losses. Maps showing average conditions are at present available, but the average alone is of little practical significance unless supplemented by data showing the relation between the average and the actual occurrences. Maps or other methods presenting data in concise form that would show the variations of the different phenomena from their averages would greatly increase the value of the maps now available.[2]

Where the weather has been under observation at or near a place for a sufficient length of time to enable one to determine the average conditions accurately,[3] an examination of the record will reveal something as to the frequency with which a phenomenon may be expected to occur in different ways. The records of all the phenomena at all the stations should be handled in the same way, a general method being employed in all cases, so that the results may be comparable. In this, as in all other statistical work, the use of frequency curves offers the most systematic method of examining the variations present in a series of observations. This method is necessarily mathematical, and in regard to the use of mathematical processes in this, or any other kind of investigation, it can only be said that—

> They are the abbreviators of long and tedious operations, and it would be perfectly possible, with sufficient time and industry, to do without their use. * * * When both the ordinary and mathematical results are derived from the same hypothesis, the latter must be the more correct; and in those numerous cases in which the difficulty lies in reducing the original circumstances to a mathematical form, there is nothing to show that we are less liable to error in deducing a common-sense result from principles too indefinite for calculation than we should be in attempting to define more closely and apply numerical reasoning.[4]

The frequency distributions, or the resulting frequency polygons of the records of most climatic phenomena, show that there is a tendency for the number of occurrences to become greater as the middle point is approached from either end, and the value that occurs oftener than any other (the mode) will generally be found to be somewhere near the average of all the observations (the mean), and the value dividing the occurrences into halves (the median) will also be near the mean.[5] The usefulness of the average is largely dependent on the assumption that these three values are very nearly, if not exactly, coincident. If the number of observations is great, i. e., if the record is a very long one, the distribution of the different frequencies will be more regular than if there are only a few observations. If it were possible to increase the number of observations indefinitely, all the irregularities would disappear and the frequency polygon would very closely approach a smooth curve, rising gradually from the base line at a point beyond that representing the lowest observed value of the variable, reaching its highest point at the value that occurred most frequently, then gradually falling away to the base line again above the highest observed value. If, in this limiting case, the polygon, or curve representing it, is symmetrical about the ordinate of the mean as an axis, the median and mode coincide with the mean, i. e., the average of all the observations is the value that occurs most frequently, and there are the same number above the average as below it. However, if the curve is not symmetrical, the mean and the mode will not coincide and the distance between them will depend upon the amount of deviation from symmetry, or skewness, present in the distribution.

In practical work it is not possible to increase the number of observations at will and the data must be used as they are found, but it may be possible to determine the ideal curve which a given frequency distribution approaches. This curve will give a frequency corresponding to any value of the variable, and if it is known, the investigator is no longer restricted to the use of the arbitrary groups of the observations themselves. From the examination of a limited number of observations, then, it becomes possible to obtain a reasonable estimate of the series of frequencies that would result from an unlimited series of observations. That is, an examination of the record of any climatic phenomenon might enable one to form an idea of the distribution to be expected.

If it can be satisfactorily demonstrated that in the long run the average value will occur more frequently than any other, and that deviations above and below the average are equally likely to occur, it is generally safe to assume that the ideal form of the distribution is that shown by the normal frequency curve. The characteristics of any distribution which can be represented by this curve can all be expressed by a single number, the standard deviation, and in order to determine the curve that will represent the ideal form of any series of data that exhibits the properties indicated above, it is only necessary to know the position of the mean and the size of the standard deviation. From this it is possible to find the portion of the total number of occurrences which will have a value greater or less than any selected amount, or the portion that will be between any two amounts; or, what is the same thing, the probability that any observed value will be greater or less than a given value, or that it will lie between any two values. Tables[6] have been

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[1] The writer wishes to record his obligation to Prof. W. J. Spillman, Chief U. S. Office of Farm Management, at whose suggestion and under whose direction this study has been undertaken.

[2] In this connection, see *Reed, W. G.* The probable growing season. MONTHLY WEATHER REVIEW, Sept., 1916, 44: 509-512, and charts.

[3] The number of observations required to deduce an accurate average depend somewhat upon the range of their values, but in any case, little weight should be given to an average obtained from less than twenty observations.

[4] De Morgan, Augustus, 1806-1871.

[5] For a more detailed discussion with examples, see *C. F. Marvin*, Elementary notes on least squares * * * for meteorology and agriculture. MONTHLY WEATHER REVIEW, Oct., 1916, 44: 551-569.

[6] *Davenport, C. B.* Statistical methods. ed. 3, New York, 1914. p. 119.
Pearson, K. Tables for statisticians and biometricians. Cambridge, 1914. p. 2.

constructed from which it is possible to find these quantities directly when the mean and standard deviation have been determined. It is evident that the use of this property of the normal curve will give much more satisfactory results than a simple count of the number of such occurrences during a given interval of time, for the shortness of the records of all climatic phenomena makes it impossible to assume that the percentage of cases which exceed a given value, say, is the same as the percentage that would be observed in the long run.

As an example, take the case of the last killing frost in Spring, the distribution of which follows the normal frequency curve, and suppose it is desired to find the ferquency with which frost should be expected after any given date at a particular station.[7] The longest available frost record in the United States covers a period of only 59 years, and it is not reasonable to assume that the frequency distribution of a record of this length is regular enough to warrant one in drawing any very close deductions from a mere count of the number of times the last frost occurred on the different dates. However, by using the frequency curve of the distribution in the manner above described, one may avoid this assumption. The form of the curve depends on the standard deviation which, in turn, is determined by the way *all* the observations are arranged, and consequently the difficulties due to the irregularities which are always present in the distribution of a small number of observations disappear. The most reliable method of finding the date after which a certain portion, say 1/20, of the last frosts should be expected to occur, would be to find the date corresponding to the point whose ordinate cuts off 1/20 of the area of the frequency curve for the distribution. An examination of the tables shows[8] that the ratio of the departure from the mean to the standard deviation, x/σ, of such a point is 1.645. That is, the date after which the last killing frost will occur in 1/20 of the years is 1.645σ days after the observed average date.

This method of procedure is comparatively simple, and where the distribution of a phenomenon is truly normal, it is possible to obtain very reliable statements of the risk from unfavorable conditions. However, the frequency distributions of most climatic phenomena are not normal, and in such cases the procedure is not nearly so simple and clear cut. A convenient and adequate test for normality is an examination of the record to find if there are the same number of occurrences on either side of the mean; that is, if the number of positive departures is equal to the number of negative departures. If these numbers are not equal, evidently the distribution is not symmetrical about the mean, and can not be accurately represented by a normal curve. It is not safe to assume that slight deviations from symmetry appearing in short records are due solely to scarcity of observations ("fluctuations of random sampling"), and that the ideal curve will be symmetrical, for in most cases found in actual practice this skewness will persist, regardless of how large the number of observations becomes.

As an example, take the record of annual rainfall at Cumberland, Md., covering a period of 37 years. In 20 of these 37 years the total rainfall was less than the average, and in 17 it was greater than the average. Now it might seem that if the record were longer, the addition of the other observations would change the position of the mean and the arrangement of the different values sufficiently to overcome this lack of symmetry. But the rainfall record at New Bedford, Mass., covering a period of 94 years, shows that the annual rainfall was less than the average 51 times, and greater than the average only 43 times. From a statistical point of view, a record of even 94 years is too short to furnish more than a rough approximation of the ideal frequencies to be expected, and accordingly the distributions at 21 stations, widely distributed over the United States, with records varying from 30 to 94 years in length, comprising a total of 963 observations of annual rainfall were combined, and even then 581, or 60 per cent, of these 963, were less than the average for their respective stations. Sir Alexander Binnie[9] has assembled the records for 14 stations widely scattered over the world, with periods of observation extending from 19 to 60 years, giving a total of 489 observations, and finds that 265, or 54 per cent of them, were below the average for their stations.

Thus the indication of skewness exhibited in a comparatively short record of 37 years is shown in about the same degree in another record nearly three times as long, and is found to be present not only in records for the entire United States, but for the whole world as well. Although this skewness is so slight that it might easily be ignored in any one record, and in fact some short records do not show this skewness at all, it is evidently not safe to make any deductions based on the assumption that the rainfall at any station for any year is just as likely to be greater as less than the average.

A further difficulty presents itself at this stage, for it is not generally possible to tell exactly, from any a priori considerations, whether the frequency distribution of any variable quantity should follow the normal law. Generally speaking, if an event is the result of a very large number of causes, all these causes independent and each contributing equally toward the resulting event, the distribution will be normal, this being, in fact, the basis of the probability curve and the normal law of error.[10] But if the number of causes is not very large, if they are not all independent of each other, or if some contribute more largely to the result than others, the frequency distribution will exhibit skewness of a greater or less degree. The amount of skewness will depend upon the difference between the nature of these causes and those necessary to give normal distribution. The varying causes of climatic phenomena are not yet known with sufficient exactness to enable one to determine in this manner the character of the distributions which they follow, and since at least 500 to 1,000 observations are necessary to construct a frequency polygon from which an ordinary count of cases would be reliable, and as it has been shown that rainfall, at least, does not follow the normal law, some other means must be devised to secure dependable results.

If we take a number of frequency distributions which tend to be symmetrical and combine them into one distribution, it is evident that the result will still be a symmetrical distribution, and it can be shown that if each of the component distributions is normal the resulting distribution will be normal. Of course, it would be impossible to determine the constants—i. e., the position of

[7] *Reed, W. G., & Tolley, H. R.* Weather as a business risk in farming. Geogr. Rev., New York, July, 1916. **2**: 48–53. *Abstract* in MONTHLY WEATHER REVIEW, June, 1916 **44**: 354–355.

[8] *Davenport, C. B.*, op. cit., p. 119; *Pearson, K.*, op. cit., p. 2. For a convenient graphic method of obtaining these ratios see *Spillman, W. J., Tolley, H. R., & Reed, W. G.* The average interval curve and it applications to meteorological phenomena. MONTHLY WEATHER REVIEW, April, 1916. **44**: 197–200.

[9] *Binnie, Alexander.* Rainfall resevoirs and water supply. New York, 1913. p. 14.

[10] *Merriman, M.* Textbook on the method of least squares. New York, 1893. p. 15 et seq.

the mean and the size of the standard deviation—for each of the components from the equation of the resulting curve, but the type would still remain. If a number of distributions exhibiting skewness of varying amounts in either direction from the mean are combined, they also will tend to give a normal distribution; but it seems reasonable to suppose that some single type of curve will represent all the distributions of annual rainfall, last killing frost in spring, or any other single phenomenon, and that this type will be that resulting from the combination of a sufficient number of records of varying length selected at random to give a smooth frequency polygon.

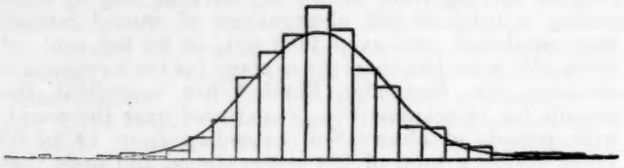

FIG. 1. Frequency polygon and best-fitting normal frequency curve of the date of last killing frost in Spring, for the combined records of 33 stations, comprising 823 observations.

This should be done by combining the departures from the mean for each record, rather than by simply arranging the absolute amounts into a frequency distribution. The means of the records would necessarily have a considerable range, and if the absolute amounts were used it is evident that the distribution resulting from the combination would be much more irregular than if departures were used in each case. If the records are arranged so that all the means coincide, and if the distributions are all of the same type, the only effect of combining them is to smooth out the irregularities in any one of them. Thus this is a kind of artificial method of obtaining an approximation to the general law governing the distribution of a phenomenon when no one record is long enough to show this law conclusively. In the case of last frost in spring the frequency polygon resulting from a combination of the records of 33 stations, with a total of 823 years of observation, was one which followed the normal curve very closely. (See fig. 1.) On account of this fact it was assumed that the distribution for every station would be normal if the number of observations were large enough, and the results of the work based on this assumption seem very satisfactory.[11]

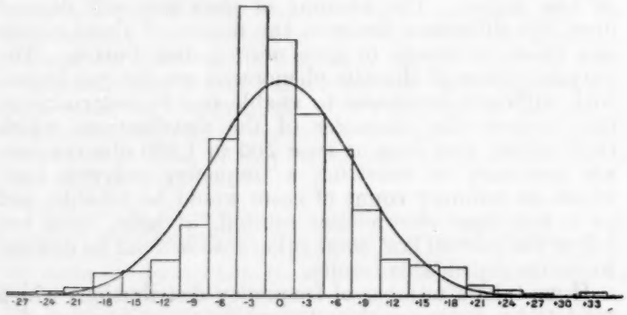

FIG. 2. Frequency polygon (in 3-inch groups) and best-fitting normal frequency curve for the combination of 21 records of annual rainfall, representing 963 observations.

The records of annual rainfall for 21 stations, with periods of observation varying from 30 to 94 years in length, with a total of 963 observations, have been combined in this manner (see fig. 2) to form a frequency polygon, and the best-fitting normal curve found. A comparison of this polygon and the resulting curve with those for the dates of last killing frost in spring (fig. 1) shows that the normal curve does not describe the fluctuations of annual rainfall nearly so well as it does those of last killing frost in spring. It is possible to determine rigidly the probability that any given distribution would be normal in the limiting case—i. e., the probability that the lack of fit is due merely to paucity of observations. ("The probability that random sampling would lead to as large or larger deviation between theory and observation.")[12] The application of this test shows that it is highly improbable that the normal curve is the limiting form of this polygon.

In a case of this kind, the calculated average has lost two of its most valuable properties. Since the mean, median, and mode are not identical, deviations above and below the mean are not equally likely to occur, and the mean is not the value that will occur most frequently. The only property remaining to the mean is the algebraic one by which it is defined; it is the sum of all the observations divided by their number. In dealing with a phenomenon like rainfall, this property might be put to some use, but it is difficult to see any purpose which it could serve in connection with a phenomenon of temperature. In a like manner, the standard deviation no longer shows the exact way in which the observations are grouped about the mean, and its accuracy as the measure of dispersion becomes less and less as the amount of skewness increases. Looking at it in another way, the position of the mean and the size of the standard deviation no longer define the distribution. In addition, it is necessary to know the position of the median and the mode, and to find some accurate measure of dispersion. The position of the median, that with the same number of observations on each side of it, can be found by counting, but we have no way of determining the probable error of this position, i. e., how much this position would change with an increase in the number of observations, and it is impossible to determine even the approximate position of the mode in a frequency distribution of so few observations as that of the ordinary climatic record.

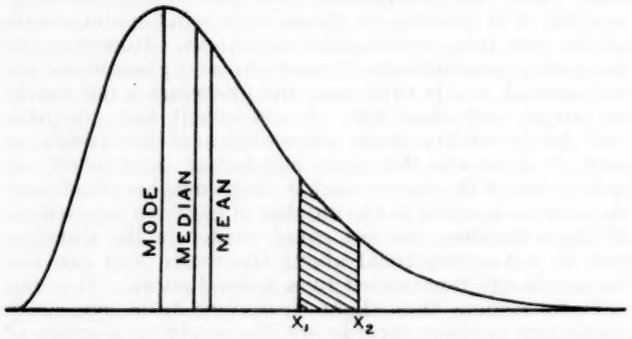

FIG. 3. A typical skew curve. (Compare *Marvin*, op. cit., p. 555, fig. 3.

If a reliable type of curve can be found to represent all the distributions of a phenomenon, and the constants of its equation determined from each record, the problem will be nearly solved. The position of the mode (see fig. 3) corresponds to the abscissa of the highest ordinate of the curve. The total area under the curve represents the number of observations, and the median is at a point such that its ordinate divides the area into two equal parts. As in the case of the normal curve, the fraction of the area to the right of any ordinate x_1 is the portion of the time that the variable can be expected to have a greater value than x_1, and the area to the left is the portion of the time it can be expected to be less than x_1,

[11] *Reed, W. G., & Tolley, H. R.* Weather as a business risk in farming. Loc. cit.

[12] *Elderton, W. P.* Frequency curves and correlation. London, 1906. p. 139 et seq. *Pearson, K.* Op. cit., 1914, p. 26

while the part between the ordinates of x_1 and x_2 is the portion of the observations which should show a value of the variable between x_1 and x_2. Presumably, all these quantities can be found if the equation of the curve is known.

If this equation be some form, say, $y=F(x)$, then since the position of the mode is at the point where the curve becomes parallel to the axis of x it can be found directly by solving the differential equation $dy/dx=0$. Any required area can be found by the use of the definite integral; for instance, the area between the ordinates of x_1 and x_2 is $\int_{x_1}^{x_2} F(x)dx$. But the great difficulty lies in obtaining a curve which will give a reasonable fit to the data, and at the same time present an equation that can be differentiated and integrated without such laborious computation as to make the work impracticable.

Various attempts have been made to find usable curves to describe skew distributions. Pearson [13] has devised a system of curves, of which the normal curve is a special case, designed to cover the entire range of skew variations, and has made extensive use of them in his researches in biology and anthropology. This theory of frequency curves is built around the general differential equation of a unimodal curve. This equation is of the form

$$\frac{1}{y}\cdot\frac{dy}{dx}=\frac{x-a}{F(x)},$$

and if $F(x)$ is expanded by Maclaurin's theorem, it becomes

$$\frac{1}{y}\cdot\frac{dy}{dx}=\frac{x-a}{c_0+c_1x+c_2x^2+\ldots}$$

The coefficients of the x's can all be determined from the observations, but on account of the uncertainty of the coefficients of the higher powers, only the first three terms of the expansion of $F(x)$ are retained. The differential equation is then integrated to find the general equation of the frequency curve, and the constants of the curve found from the first, second, third, and fourth powers of the departures from the mean of the observations composing the frequency distribution under consideration. However, the resulting equations of the frequency curves are so complicated, and the computation of the constants so lengthy an operation, that the task of analyzing the data at any great number of stations for even one climatic phenomenon would be hopeless. Also it is not possible to integrate the equations of the curves in the general case, and consequently a general expression for the area between any two ordinates can not be obtained. Of course, they give a theoretical position for the median and the mode, and the number of occurrences of any particular amount, but the main part of the problem in dealing with climatic data is to find the portion of the occurrences greater or less than a given amount, and for this they seem to offer little aid.

Others,[14] by an extension of the method from which the normal law was deduced, have developed a theory for skew variation which gives curves more closely allied with the normal curve, and although they do not cover the entire field as thoroughly as do Pearson's formulæ, a study of the forms of the equations and the calculations of the necessary constants compels one to conclude that in the analysis of climatic data they are much more useful than Pearson's better known forms.

If we call this theory the generalized law of frequency, the equation of the generalized frequency curve is

$$y=A_0F(x)+A_1F^{\mathrm{I}}(x)+A_2F^{\mathrm{II}}(x)+A_3F^{\mathrm{III}}(x)+A_4F^{\mathrm{IV}}(x)+\ldots$$

where

$$F(x)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{x^2}{2\sigma^2}}$$

the equation of the normal curve; $F^{\mathrm{I}}(x)$, $F^{\mathrm{II}}(x)$, etc., are the first, second, and higher derivatives of $F(x)$ and the A's are coefficients independent of x, to be determined from the series of observations under consideration. If the origin is taken at the mean, and if for simplicity, the entire area of the curve is designated as unity, the coefficient A_0 becomes unity, A_1 and A_2 are each equal to zero, and the equation reduces to

$$y=F(x)+A_3F^{\mathrm{III}}(x)+A_4F^{\mathrm{IV}}(x)+\ldots$$

The coefficients A_3, A_4, etc., are functions of the third, fourth, and higher powers, respectively, of the departures of the individual observations from their mean.[15] If we call the average of the cubes of the departures μ_3 the average of the fourth powers, μ_4, etc., then

$$A_3=-\frac{\mu_3}{\underline{3}}$$

$$A_4=\frac{\mu_4-3\sigma^4}{\underline{4}}$$

Now if the observations follow the normal law these coefficients, together with all the following ones vanish, and the equation reduces to that of the normal curve. If the distribution is symmetrical, the cubes of all the negative departures will balance the cubes of all the positive departures, and μ_3 will reduce to 0. The value of μ_3 will increase with the skewness, and its sign will show the direction; if the sign is positive, most of the observations will lie below the mean, and consequently the value of the mode will be less than the mean, while if it is negative the reverse will be true. If the skewness is no greater than that found in the distributions of climatic phenomena so far examined, the series is rapidly convergent. The first term, $F(x)$, dominates the entire series, except near the ends of the distribution, and the coefficients of the derivatives of higher order decrease so rapidly in size that the first two or three terms describe the distribution as closely as the number of observations warrant.

The use of the terms of higher order will, of course, give an equation containing a greater number of constants, and on that account will give a closer approximation to any limited set of observations, but the probable error of the constants derived from the higher powers of the departures is large, and because of this it is doubtful if the use of a large number of terms of the series would enable one to make any better estimate of what the frequency distribution of a climatic record would be in the ideal case, than that which can be made from a consideration of only the first (mean), second (standard deviation), and third powers.

[13] *Pearson, K.* Skew variation in homogeneous material. Phil. trans., Roy. Soc., London, 1895, Ser. **A, 186:** 343–414.

[14] *Edgeworth, F. Y.* The generalized law of error. Journal, Roy. Stat. Soc., London, 1906, **69:** 497–530.
Thiele, T. N. Theory of observations. London, 1903.
Charlier, C. V. L. Researches into the theory of probability. Lund Universitet, Observatoriet . . . Meddelanden . . . Ser. 2, nr. 4. (Kongl. Fysiografiska Sallskapets Handlingar, N. F., bd. **16,** nr. 5). Lund, 1906.

[15] This method of determining the constants of a curve from the successive powers of the departures is termed the *method of moments* (cf. moments of inertia), for an explanation of which see *Pearson, K.*, The systematic fitting of curves to observations and measurements. Biometrika, v. 1, pp. 265–303; v. 2, pp. 1–23, April Nov., 1902; *Elderton, W. P.*, Frequency curves and correlation. London, 1906. pp. 13–35.

Any presumptive distribution based on the higher coefficients can be of little value as far as these higher coefficients affect it, on account of the fact that the averages of the sums of the higher powers of the departures are liable to great change as the number of observations increase. It has been found that coefficients involving higher powers than the fourth are valueless, even when there are several hundred observations,[16] and consequently the coefficients involving powers higher than the third can be of little value in determining the ideal distribution when the record consists of less than one hundred observations.

The equation then reduces to the form,

$$y = F(x) + A_3 F^{\text{III}}(x)$$

which becomes

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \left[1 - \frac{\mu_3}{\underline{3}\sigma^3}\left(\frac{x}{\sigma} - \frac{x^3}{\sigma^3}\right)\right]$$

when the values already defined are given to A_3, $F(x)$, and $F^{\text{III}}(x)$. In order to construct this curve, it is necessary to compute only one constant, μ_3, besides the mean and the standard deviation (see fig. 4).

The equation can be integrated readily and the area between any two ordinates determined. Taking the form

$$y = F(x) + A_3 F^{\text{III}}(x),$$

the indefinite integral is

$$\int y dx = \int F(x)dx + A_3 F^{\text{III}}(x),$$

which upon reduction gives

$$\int_{x_1}^{x_2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} dx - \left[\frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \cdot \frac{k}{\underline{3}}\left(\frac{x^2}{\sigma^2} - 1\right)\right]_{x=x_1}^{x=x_2}$$

where $k = \mu_3/\sigma^3$ for the area between the two ordinates whose departures from the mean are (positive) x_1 and x_2. The area beyond (to the right of) the ordinate of any positive departure x_1, is given by

$$\int_{x_1}^{\infty} F(x)dx - \left[\frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \cdot \frac{k}{\underline{3}}\left(\frac{x^2}{\sigma^2} - 1\right)\right]_{x=x_1}^{x=\infty}$$

Since the entire area of the curve has been made equal to unity, the area to the left of the ordinate of x_1 is given by

$$\int_{-\infty}^{x_1} F(x)dx + \left[\frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \cdot \frac{k}{\underline{3}}\left(\frac{x^2}{\sigma^2} - 1\right)\right]_{x=x_1}^{x=\infty}$$

The sum of the two quantities is the entire area of the curve, and upon addition they give

$$\int_{-\infty}^{x_1} F(x)dx + \int_{x_1}^{\infty} F(x)dx,$$

[16] *Pearson, K.* Mathematical contributions to the theory of evolution, XIV: The general theory of skew correlation and nonlinear regression. Drapers Co. Research Memoirs, Biometric Series II. London, 1905. p. 7 et seq.

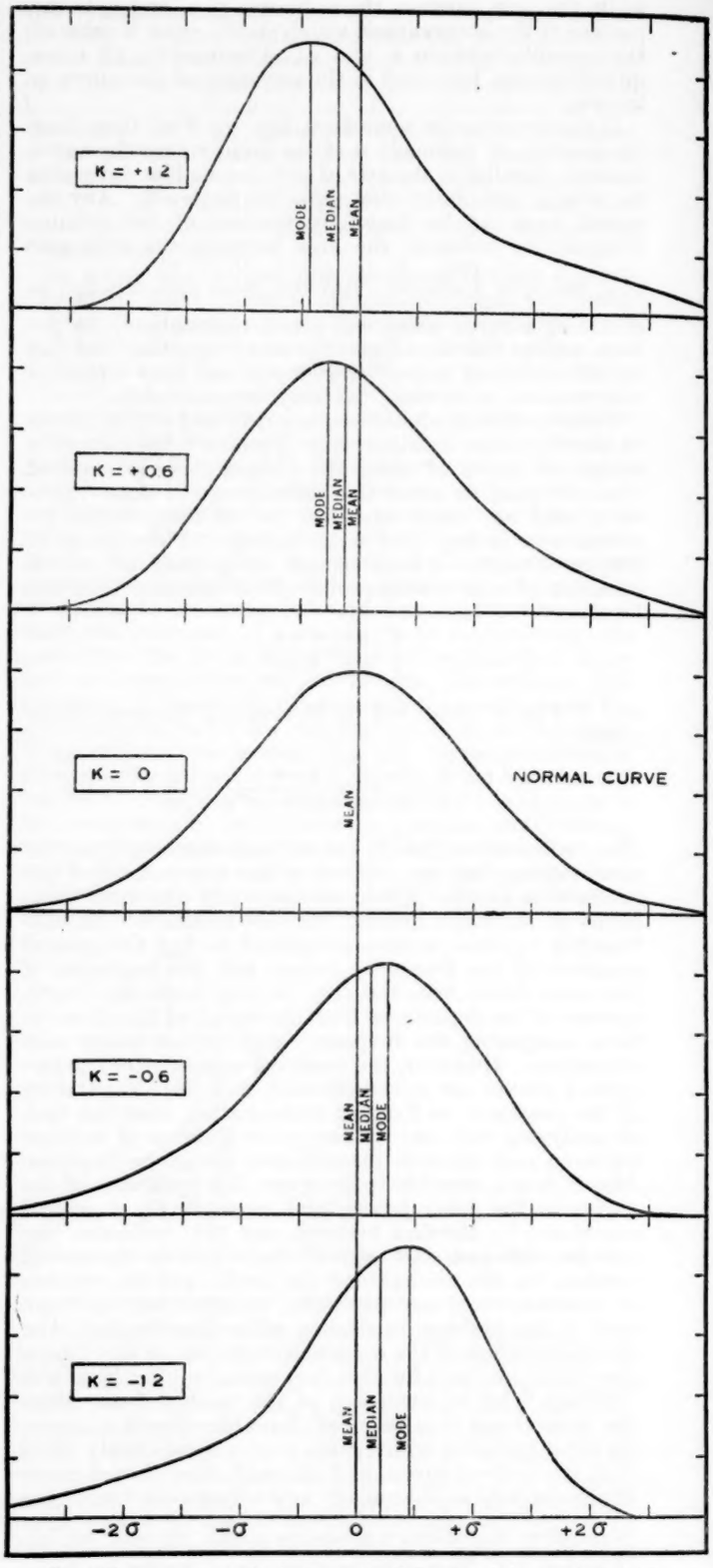

FIG. 4. Frequency curves showing amount and direction of skewness indicated by different values of k.

which is the entire area of the normal curve and equal to unity. The quantity enclosed in the brackets vanishes when $x=\infty$, and it can be evaluated by direct computation [17] for different values of k and σ. The first term $\int F(x)dx$ is the integral of the equation of the normal curve, and its value can be obtained from the tables of Pearson or Davenport. The two terms can then be combined to form new tables, which will give immediately the portion of the area of the skew curve on either side of any ordinate when k and σ are known for the distribution. Tables giving the percentage of the area of the curve to the left of the ordinate whose abscissa is x, have been prepared for values of k, at intervals of 0.2 from $k=-1.4$ to $k=+1.4$, and values of x/σ at intervals of 0.05, from $x/\sigma=-3.00$ to $x/\sigma=+3.00$. (Table 1.) By interpolation from this table, it is possible to find, to four places of decimals, the portion of the area on either side of any ordinate or that between any two ordinates, or what is the same thing, the probability of an observation being greater or less than any given value, or the probability of its lying between any two selected values.

The reciprocal of the probability of the occurrence of an event may be called the *average interval* between such occurrences. For instance, if it has been found that one-fifth of the observations of annual rainfall at a station should be below a certain amount, then the probability of the rainfall for any year being less than this amount is one-fifth. and the average interval between occurrences of rainfall less than this amount is five years. If, then, the reciprocals of the quantities (considered as percentages) given in Table 1 are plotted against their respective values of x/σ, the resulting family of curves could be used to find the average interval between occurrences greater or less than any selected amount.[18] Such curves are easily constructed and in many cases where meteorological data are under consideration, their use will be found preferable to that of the tables. The use of these curves, to find the appropriate value of x/σ for any given average interval, or vice versa, when k is known, requires less time than the use of the tables, and if the curves are properly constructed, values thus found will generally have an accuracy comparable to that of the observations themselves.

The use of the skew curves, and the resulting table, has been tested in the case of 38 records of minimum winter temperatures, in an attempt to find the values below which the temperature should not be expected to fall oftener than once in 10 years on the average. There is a lack of symmetry in the frequency distributions of winter minima about equal to that in those of annual rainfall, but it is in the opposite direction, the greater number of the observations being above the mean instead of below it. The departure, below the mean, of the value which the winter minimum will exceed in one-tenth of the years, or below which the probability of an occurrence is 1/10, will be represented by the abscissa whose ordinate cuts off 10% of the area from the lower (left) end of the frequency curve derived from the observations. The actual computations in any case necessary to find this value would be somewhat as follows (see Table 2):

(1) Find the mean, M_0, the standard deviation, σ, and the average of the cubes of the departures from the mean, μ_3. In the example, $M_0=+16.67°$F., $\sigma=7.37$, and $\mu_3=-276.23$.

(2) Find the value of k, from the formula $k=\mu_3/\sigma^3$. In the example, $k=-0.69$.

(3) For the value of k thus found, determine from Table 1 the value of x/σ which corresponds to 10% of the area of the curve. For $k=-0.69$, this value is -1.378.

(4) Multiply the standard deviation, σ, by the value of x/σ thus found and subtract the product from the mean, M_0. For Portland, Oreg., the resulting value is +6.51°F. The probability that the temperature will fall below the value thus obtained is 1/10, or what is the same thing, the temperature should fall below this value once in 10 years on the average.

An abstract of the computation of this value for each of the 38 selected stations is given in Table 3. An examination of the k's for the different records bears out the statement already made that there are generally a greater number of observations above the mean than below it. At all except four of the stations, k is negative. The sign of k depends upon the sign of μ_3, and as already stated, if this sign is negative, most of the observations lie above the mean and the value of the mode is greater than that of the mean.

These computed values can not be expected to agree exactly with those found by a simple count of the lowest observed values in each record, i. e., although all the records examined were approximately 40 years in length, it is not to be expected that the computed values below which the temperature should fall in 1/10 of the years would have been exceeded exactly four times in each record. However, the differences between these computed values and those found by counting should be promiscuous, and the two methods should agree in the aggregate. If we add together the number of observations in each record which fall below this computed value the sum should be very nearly one-tenth of the total number of observations. In these 38 records, with a total of 1,519 observations, 150 observations fell below the values computed by this method. Similar values were computed at each station, on the assumption that the distribution was normal ($k=0$), by simply subtracting 1.28σ from the mean, and it was found that 173 of the 1,519 observations fell below these values. This shows that the skew curves are much more accurate, at least for this purpose, than the normal curve.

The method was tested further by computing, for each of these stations, the value below which the temperature should fall 9 years in 10 on the average. The probability that the minimum temperature will be above such a value is 1/10, and the departure above the mean of that value will be represented by the abscissa whose ordinate cuts off 10% of the area from the upper (right) end of the frequency curve. The procedure then was the same as that outlined above, except that the value of x/σ which corresponds to 90% of the area of the curve was determined for the proper value of k in each case, and the resulting value of x was added to the mean instead of subtracted from it. Here it was found that 144 of the 1,519 observations were above the values thus computed. This is not quite such close agreement as that found above, but it is considerably better than that given by assuming normal distribution. There were only 127 occurrences above the values computed by adding 1.28σ to the mean in each case. Thus, in an endeavor to find values that should be exceeded in 10 per cent of the cases, the use of the normal curve gave values which were exceeded by only 8.3 per cent of the occurrences; while the use of the skew curves, where k as well as σ was taken into account, gave values that were exceeded by 9.5 per cent of the occurrences.

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[17] For a table of values of the quantity $\frac{1}{\sqrt{2\pi}}e^{-\frac{x^2}{\sigma^2}}$, for varying values of $\frac{x}{\sigma}$, see *Pearson, K.* Tables for Statisticians and Biometricians. Cambridge, 1914. Table II, pp. 2–8.

[18] For an explanation of the construction and some of the uses of the average interval curve for normal distributions see *Spillman, W. J., Tolley, H. R., & Reed, W. G.*, The average interval curve and its application to meteorological phenomena, MONTHLY WEATHER REVIEW April, 1916, 44: 197–200.

TABLE 1.—*Area of skew frequency curves in terms of the abscissa.*

(Total area of curve=100.)

$\frac{x}{\sigma}$	Values of k.														
	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	0.0	+0.2	+0.4	+0.6	+0.8	+1.0	+1.2	+1.4
−3.00	0.962	0.844	0.726	0.608	0.490	0.371	0.253	0.135	0.017	.....	.....	.....	.....	.....	.....
−2.95	1.083	.951	.819	.687	.555	.423	.291	.159	.027	.....	.....	.....	.....	.....	.....
−2.90	1.216	1.069	.922	.775	.628	.481	.334	.187	.040	.....	.....	.....	.....	.....	.....
−2.85	1.361	1.198	1.034	.871	.708	.545	.382	.219	.055	.....	.....	.....	.....	.....	.....
−2.80	1.519	1.338	1.158	.977	.797	.616	.436	.256	.075	.....	.....	.....	.....	.....	.....
−2.75	1.690	1.492	1.293	1.094	0.895	0.696	0.497	0.298	0.099	.....	.....	.....	.....	.....	.....
−2.70	1.876	1.658	1.439	1.221	1.002	.784	.565	.347	.128	.....	.....	.....	.....	.....	.....
−2.65	2.076	1.837	1.598	1.359	1.120	.881	.642	.402	.163	.....	.....	.....	.....	.....	.....
−2.60	2.292	2.031	1.770	1.509	1.248	.988	.727	.466	.205	.....	.....	.....	.....	.....	.....
−2.55	2.522	2.239	1.955	1.672	1.389	1.105	.822	.539	.255	.....	.....	.....	.....	.....	.....
−2.50	2.768	2.461	2.155	1.848	1.541	1.234	0.928	0.621	0.314	0.007	.....	.....	.....	.....	.....
−2.45	3.030	2.699	2.368	2.037	1.707	1.376	1.045	.714	.383	.053	.....	.....	.....	.....	.....
−2.40	3.307	2.952	2.596	2.241	1.886	1.530	1.175	.820	.464	.109	.....	.....	.....	.....	.....
−2.35	3.600	3.220	2.839	2.459	2.079	1.699	1.319	.939	.559	.178	.....	.....	.....	.....	.....
−2.30	3.908	3.503	3.098	2.693	2.288	1.883	1.477	1.072	.667	.262	.....	.....	.....	.....	.....
−2.25	4.231	3.801	3.371	2.942	2.512	2.082	1.652	1.222	0.793	0.363	.....	.....	.....	.....	.....
−2.20	4.569	4.115	3.661	3.207	2.753	2.298	1.844	1.390	.936	.482	0.028	.....	.....	.....	.....
−2.15	4.921	4.443	3.966	3.488	3.010	2.533	2.055	1.578	1.100	.623	.145	.....	.....	.....	.....
−2.10	5.286	4.786	4.286	3.786	3.286	2.786	2.286	1.786	1.286	.787	.287	.....	.....	.....	.....
−2.05	5.664	5.143	4.622	4.102	3.581	3.060	2.539	2.018	1.497	.977	.456	.....	.....	.....	.....
−2.00	6.054	5.514	4.975	4.435	3.895	3.355	2.815	2.275	1.735	1.195	0.655	0.115	.....	.....	.....
−1.95	6.456	5.899	5.342	4.786	4.229	3.672	3.116	2.559	2.002	1.445	.889	.332	.....	.....	.....
−1.90	6.868	6.297	5.726	5.155	4.584	4.013	3.443	2.872	2.301	1.730	1.159	.588	0.017	.....	.....
−1.85	7.289	6.707	6.125	5.543	4.961	4.380	3.798	3.216	2.634	2.052	1.470	.888	.306	.....	.....
−1.80	7.720	7.130	6.540	5.951	5.362	4.772	4.183	3.593	3.004	2.414	1.825	1.235	.646	0.056	.....
−1.75	8.158	7.565	6.972	6.379	5.785	5.192	4.599	4.006	3.412	2.820	2.226	1.633	1.040	0.447	.....
−1.70	8.604	8.012	7.419	6.827	6.234	5.642	5.049	4.457	3.864	3.272	2.679	2.087	1.494	.901	0.309
−1.65	9.057	8.470	7.883	7.296	6.709	6.121	5.534	4.947	4.360	3.773	3.186	2.598	2.011	1.424	.837
−1.60	9.517	8.941	8.364	7.787	7.210	6.634	6.057	5.480	4.903	4.326	3.750	3.173	2.596	2.019	1.442
−1.55	9.984	9.423	8.862	8.301	7.740	7.179	6.618	6.057	5.496	4.935	4.374	3.813	3.252	2.691	2.130
−1.50	10.458	9.919	9.379	8.839	8.300	7.760	7.220	6.681	6.141	5.601	5.062	4.522	3.982	3.443	2.903
−1.45	10.940	10.427	9.915	9.403	8.890	8.378	7.865	7.353	6.841	6.328	5.816	5.303	4.791	4.278	3.766
−1.40	11.430	10.950	10.471	9.992	9.513	9.034	8.555	8.076	7.597	7.117	6.638	6.159	5.680	5.201	4.722
−1.35	11.929	11.489	11.049	10.610	10.170	9.730	9.291	8.851	8.411	7.971	7.532	7.092	6.652	6.212	5.773
−1.30	12.439	12.045	11.651	11.257	10.862	10.468	10.074	9.680	9.286	8.892	8.498	8.103	7.709	7.315	6.921
−1.25	12.962	12.620	12.277	11.935	11.592	11.250	10.907	10.565	10.223	9.880	9.538	9.195	8.853	8.510	8.168
−1.20	13.501	13.216	12.931	12.646	12.361	12.077	11.792	11.507	11.222	10.937	10.653	10.368	10.083	9.798	9.513
−1.15	14.057	13.835	13.614	13.393	13.171	12.950	12.729	12.507	12.286	12.064	11.843	11.622	11.400	11.179	10.958
−1.10	14.634	14.482	14.329	14.177	14.024	13.872	13.719	13.567	13.414	13.262	13.109	12.957	12.804	12.652	12.499
−1.05	15.236	15.157	15.079	15.000	14.922	14.843	14.764	14.686	14.607	14.529	14.450	14.372	14.293	14.215	14.136
−1.00	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866	15.866
−0.95	16.528	16.610	16.693	16.775	16.858	16.940	17.023	17.106	17.188	17.271	17.353	17.436	17.518	17.601	17.684
− .90	17.226	17.395	17.563	17.732	17.900	18.069	18.237	18.406	18.575	18.743	18.912	19.080	19.249	19.417	19.586
− .85	17.966	18.223	18.481	18.738	18.995	19.252	19.509	19.766	20.023	20.281	20.538	20.795	21.052	21.309	21.566
− .80	18.752	19.100	19.447	19.795	20.143	20.490	20.838	21.186	21.533	21.881	22.228	22.576	22.924	23.271	23.619
−0.75	19.589	20.028	20.467	20.906	21.345	21.784	22.224	22.663	23.102	23.541	23.980	24.419	24.859	25.298	25.737
− .70	20.481	21.011	21.542	22.073	22.604	23.135	23.666	24.196	24.727	25.258	25.789	26.320	26.851	27.381	27.912
− .65	21.433	22.054	22.676	23.298	23.919	24.541	25.163	25.785	26.406	27.028	27.650	28.272	28.893	29.515	30.137
− .60	22.449	23.160	23.871	24.582	25.293	26.004	26.714	27.425	28.136	28.847	29.558	30.269	30.980	31.691	32.401
− .55	23.535	24.332	25.129	25.927	26.724	27.521	28.319	29.116	29.913	30.711	31.508	32.305	33.103	33.900	34.697
−0.50	24.693	25.573	26.453	27.333	28.213	29.093	29.974	30.854	31.734	32.614	33.494	34.374	35.255	36.135	37.015
− .45	25.927	26.885	27.844	28.802	29.760	30.719	31.677	32.636	33.594	34.552	35.511	36.469	37.428	38.386	39.344
− .40	27.240	28.271	29.302	30.333	31.364	32.396	33.427	34.458	35.489	36.520	37.551	38.582	39.614	40.645	41.676
− .35	28.634	29.731	30.829	31.927	33.024	34.122	35.219	36.317	37.415	38.512	39.610	40.707	41.805	42.902	44.000
− .30	30.111	31.268	32.424	33.581	34.738	35.895	37.052	38.209	39.366	40.523	41.679	42.836	43.993	45.150	46.307
−0.25	31.671	32.879	34.088	35.296	36.504	37.713	38.921	40.129	41.338	42.546	43.754	44.963	46.171	47.379	48.588
− .20	33.315	34.566	35.817	37.069	38.320	39.571	40.823	42.074	43.325	44.577	45.828	47.079	48.331	49.582	50.833
− .15	35.041	36.326	37.612	38.897	40.182	41.468	42.753	44.038	45.324	46.609	47.894	49.180	50.465	51.750	53.036
− .10	36.848	38.158	39.468	40.777	42.087	43.397	44.707	46.017	47.327	48.637	49.947	51.257	52.567	53.877	55.187
− .05	38.732	40.057	41.382	42.707	44.032	45.356	46.681	48.006	49.331	50.656	51.981	53.305	54.630	55.955	57.280
0.00	40.691	42.021	43.351	44.681	46.011	47.340	48.670	50.000	51.330	52.660	53.989	55.319	56.649	57.979	59.309

TABLE 1.—*Area of skew frequency curves in terms of the abscissa*—Continued.

(Total area of curve=100.)

$\frac{x}{\sigma}$	Values of k.														
	−1.4	−1.2	−1.0	−0.8	−0.6	−0.4	−0.2	−0.0	+0.2	+0.4	+0.6	+0.8	+1.0	+1.2	+1.4
0.00	40.691	42.021	43.351	44.681	46.011	47.340	48.670	50.000	51.330	52.660	53.989	55.319	56.649	57.979	59.309
+0.05	42.720	44.045	45.370	46.695	48.019	49.344	50.669	51.994	53.319	54.644	55.968	57.293	58.618	59.943	61.268
.10	44.813	46.123	47.433	48.743	50.053	51.363	52.673	53.983	55.293	56.603	57.913	59.223	60.532	61.842	63.152
.15	46.964	48.250	49.535	50.820	52.106	53.391	54.676	55.962	57.247	58.532	59.818	61.103	62.388	63.674	64.959
.20	49.167	50.418	51.669	52.921	54.172	55.423	56.675	57.926	59.177	60.429	61.680	62.931	64.183	65.434	66.685
.25	51.412	52.621	53.829	55.037	56.246	57.454	58.662	59.871	61.079	62.287	63.496	64.704	65.912	67.121	68.329
+0.30	53.693	54.850	56.007	57.164	58.321	59.477	60.634	61.791	62.948	64.105	65.262	66.419	67.576	68.732	69.889
.35	56.000	57.098	58.195	59.293	60.390	61.488	62.585	63.683	64.781	65.878	66.976	68.073	69.171	70.269	71.366
.40	58.324	59.355	60.386	61.418	62.449	63.480	64.511	65.542	66.573	67.604	68.636	69.667	70.698	71.729	72.760
.45	60.656	61.614	62.572	63.531	64.489	65.448	66.406	67.364	68.323	69.281	70.240	71.198	72.156	73.115	74.073
.50	62.985	63.865	64.745	65.626	66.506	67.386	68.266	69.146	70.026	70.907	71.787	72.667	73.547	74.427	75.307
+0.55	65.303	66.100	66.897	67.695	68.492	69.289	70.087	70.884	71.681	72.479	73.276	74.073	74.871	75.668	76.465
.60	67.599	68.309	69.020	69.731	70.442	71.153	71.864	72.575	73.286	73.996	74.707	75.418	76.129	76.840	77.551
.65	69.863	70.485	71.107	71.728	72.350	72.972	73.594	74.215	74.837	75.459	76.081	76.702	77.324	77.946	78.567
.70	72.088	72.619	73.149	73.680	74.211	74.742	75.273	75.804	76.334	76.865	77.396	77.927	78.458	78.989	79.519
.75	74.263	74.702	75.141	75.581	76.020	76.459	76.898	77.337	77.776	78.216	78.655	79.094	79.533	79.972	80.411
+0.80	76.381	76.729	77.076	77.424	77.772	78.119	78.467	78.814	79.162	79.510	79.857	80.205	80.553	80.900	81.248
.85	78.434	78.691	78.948	79.205	79.462	79.719	79.977	80.234	80.491	80.748	81.005	81.262	81.519	81.777	82.034
.90	80.414	80.583	80.751	80.920	81.088	81.257	81.425	81.594	81.763	81.931	82.100	82.268	82.437	82.605	82.774
.95	82.316	82.399	82.481	82.564	82.647	82.729	82.812	82.894	82.977	83.060	83.142	83.225	83.307	83.390	83.472
1.00	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134	84.134
+1.05	85.864	85.785	85.707	85.629	85.550	85.471	85.393	85.314	85.236	85.157	85.078	85.000	84.921	84.843	84.764
1.10	87.501	87.348	87.196	87.043	86.891	86.738	86.586	86.433	86.281	86.128	85.976	85.823	85.671	85.518	85.366
1.15	89.042	88.821	88.600	88.378	88.157	87.935	87.714	87.493	87.271	87.050	86.829	86.607	86.386	86.165	85.943
1.20	90.487	90.202	89.917	89.632	89.347	89.063	88.778	88.493	88.208	87.923	87.639	87.354	87.069	86.784	86.499
1.25	91.832	91.490	91.147	90.805	90.462	90.120	89.777	89.435	89.093	88.750	88.408	88.065	87.723	87.380	87.038
+1.30	93.079	92.685	92.291	91.897	91.502	91.108	90.714	90.320	89.926	89.532	89.138	88.743	88.349	87.955	87.561
1.35	94.227	93.788	93.348	92.908	92.468	92.029	91.589	91.149	90.709	90.270	89.830	89.390	88.951	88.511	88.071
1.40	95.278	94.799	94.320	93.841	93.362	92.883	92.404	91.924	91.445	90.966	90.487	90.008	89.529	89.050	88.570
1.45	96.234	95.722	95.209	94.697	94.184	93.672	93.159	92.647	92.135	91.622	91.110	90.597	90.085	89.573	89.060
1.50	97.097	96.557	96.018	95.478	94.938	94.399	93.859	93.319	92.780	92.240	91.700	91.161	90.621	90.081	89.542
+1.55	97.870	97.309	96.748	96.187	95.626	95.065	94.504	93.943	93.382	92.821	92.260	91.699	91.138	90.577	90.016
1.60	98.558	97.981	97.404	96.827	96.250	95.674	95.097	94.520	93.943	93.366	92.790	92.213	91.636	91.059	90.483
1.65	99.163	98.576	97.989	97.402	96.814	96.227	95.640	95.053	94.466	93.879	93.291	92.704	92.117	91.530	90.943
1.70	99.691	99.099	98.506	97.913	97.321	96.728	96.136	95.543	94.951	94.358	93.766	93.173	92.581	91.988	91.396
1.75	.....	99.553	98.960	98.367	97.774	97.180	96.587	95.994	95.401	94.808	94.215	93.621	93.028	92.435	91.842
+1.80	.....	99.944	99.354	98.765	98.175	97.586	96.996	96.407	95.817	95.228	94.638	94.049	93.460	92.870	92.281
1.85	.....	.....	99.694	99.112	98.530	97.948	97.366	96.784	96.202	95.620	95.039	94.457	93.875	93.293	92.711
1.90	.....	.....	99.983	99.412	98.841	98.270	97.699	97.128	96.557	95.987	95.416	94.845	94.274	93.703	93.132
1.95	.....	.....	.....	99.668	99.111	98.555	97.998	97.441	96.884	96.328	95.771	95.214	94.658	94.101	93.544
2.00	.....	.....	.....	99.885	99.345	98.805	98.265	97.725	97.185	96.645	96.105	95.565	95.025	94.486	93.946
+2.05	.....	.....	.....	.....	99.544	99.023	98.503	97.982	97.461	96.940	96.419	95.898	95.378	94.857	94.336
2.10	.....	.....	.....	.....	99.713	99.213	98.714	98.214	97.714	97.214	96.714	96.214	95.714	95.214	94.714
2.15	.....	.....	.....	.....	99.855	99.377	98.900	98.422	97.945	97.467	96.990	96.512	96.034	95.557	95.079
2.20	.....	.....	.....	.....	99.972	99.518	99.064	98.610	98.156	97.702	97.247	96.793	96.339	95.885	95.431
2.25	.....	.....	.....	.....	.....	99.637	99.207	98.778	98.348	97.918	97.488	97.058	96.629	96.199	95.769
+2.30	.....	.....	.....	.....	.....	99.738	99.333	98.928	98.523	98.117	97.712	97.307	96.902	96.497	96.092
2.35	.....	.....	.....	.....	.....	99.822	99.441	99.061	98.681	98.301	97.921	97.541	97.161	96.780	96.400
2.40	.....	.....	.....	.....	.....	99.891	99.536	99.180	98.825	98.470	98.114	97.759	97.404	97.048	96.693
2.45	.....	.....	.....	.....	.....	99.947	99.617	99.286	98.955	98.624	98.293	97.963	97.632	97.301	96.970
2.50	.....	.....	.....	.....	.....	99.993	99.686	99.379	99.072	98.766	98.459	98.152	97.845	97.539	97.232
+2.55	.....	.....	.....	.....	.....	.....	99.745	99.461	99.178	98.895	98.611	98.328	98.045	97.761	97.478
2.60	.....	.....	.....	.....	.....	.....	99.795	99.534	99.273	99.012	98.752	98.491	98.230	97.969	97.708
2.65	.....	.....	.....	.....	.....	.....	99.837	99.598	99.358	99.119	98.880	98.641	98.402	98.163	97.924
2.70	.....	.....	.....	.....	.....	.....	99.872	99.653	99.435	99.216	98.998	98.779	98.561	98.342	98.124
2.75	.....	.....	.....	.....	.....	.....	99.901	99.702	99.503	99.304	99.105	98.906	98.707	98.508	98.310
+2.80	.....	.....	.....	.....	.....	.....	99.925	99.744	99.564	99.383	99.203	99.023	98.842	98.662	98.481
2.85	.....	.....	.....	.....	.....	.....	99.945	99.781	99.618	99.455	99.292	99.129	98.966	98.802	98.639
2.90	.....	.....	.....	.....	.....	.....	99.960	99.813	99.666	99.519	99.372	99.225	99.078	98.931	98.784
2.95	.....	.....	.....	.....	.....	.....	99.973	99.841	99.709	99.577	99.445	99.313	99.181	99.049	98.917
3.00	.....	.....	.....	.....	.....	.....	99.983	99.865	99.747	99.629	99.510	99.392	99.274	99.156	99.038

TABLE 2.—*Calculation of value below which the winter minimum will fall once in 10 years, on the average, at Portland, Oreg.*

Year.	Minimum temperature.	d.	d^2.	d^3.
	°F.	°F.		
1888	−2	−19	361	−6,859
1875	3	−14	196	−2,744
1879	3	−14	196	−2,744
1909	6	−11	121	−1,331
1883	7	−10	100	−1,000
1884	7	−10	100	−1,000
1893	8	− 9	81	− 729
1887	9	− 8	64	− 512
1889	9	− 8	64	− 512
1890	10	− 7	49	− 343
1896	11	− 6	36	− 216
1902	13	− 4	16	− 64
1907	13	− 4	16	− 64
1886	15	− 2	4	− 8
1885	17	0	0	0
1905	17	0	0	0
1878	18	1	1	1
1882	18	1	1	1
1894	18	1	1	1
1880	19	2	4	8
1900	19	2	4	8
1876	20	3	9	27
1892	20	3	9	27
1912	20	3	9	27
1898	21	4	16	64
1910	21	4	16	64
1897	22	5	25	125
1906	22	5	25	125
1913	22	5	25	125
1889	23	6	36	216
1891	23	6	36	216
1908	23	6	36	216
1911	23	6	36	216
1881	24	7	49	343
1903	24	7	49	343
1877	25	8	64	512
1895	25	8	64	512
1901	26	9	81	729
1904	28	11	121	1,331
Sums		−13	2,121	−12,889
Mean	16.67			

COMPUTATION.

Quantity.	Symbol.	Value.
Number of years of observation	n	39
Mean winter minimum	M_0	+16.67°F.
Convenient number near the mean	M	+17°
Departure from M	d	
Sum of column d	Σd	−13
Average departure from M	$\Sigma d/n$	− 0.33
Sum of column d^2	Σd^2	+2,121
Average of square of departures from M	$\Sigma d^2/n$	+54.38
Average of square of departures from the mean[1]	$\frac{\Sigma d^2}{n}-\left(\frac{\Sigma d}{n}\right)^2$	+54.27
Standard deviation	$\sigma=\sqrt{\frac{\Sigma d^2}{n}-\left(\frac{\Sigma d}{n}\right)^2}$	7.37
Sum of column d^3	Σd^3	−12,889
Average of cube of departures from M	$\Sigma d^3/n$	−330.48
Average of cube of departures from the mean[1]	$\mu_3=\frac{\Sigma d^3}{n}-3\left(\frac{\Sigma d}{n}\right)\left(\frac{\Sigma d^2}{n}\right)+2\left(\frac{\Sigma d}{n}\right)^3$	−276.23
k	$k=\mu_3/\sigma^3$	−0.69
Value from Table 1, for $k=-0.69$, and *average interval*=10	x/σ	−1.378
Departure below mean that will be exceeded in 1/10 of the years	$x=1.378\sigma$	10.16°F.
Value below which winter minimum will fall in 1/10 of the years	M_0-x	+6.51°F.

[1] See *Davenport, C. B.*: Statistical methods, ed. 3, 1914, pp. 20–21, for formulæ reducing these quantities to the true mean. The notation in the table is different from that used by Davenport.

TABLE 3.—*Abstract of computation of values of minimum winter temperatures (t) which should be exceeded, on the average, once in 10 years.*

State.	Station.	Number of observations. n.	Mean minimum temperature.	σ	k	$\frac{x}{\sigma}$ (from Table 1).	Departures of t from mean.	t.	Number of observations below t.
			°F.				°F.	°F.	
Alabama	Mobile	42	+21.19	6.29	−0.93	1.427	− 8.98	+12.21	3
Do	Montgomery	41	+16.95	6.30	−1.02	1.448	− 9.12	+ 7.83	2
California	San Diego	42	+35.62	2.95	−0.45	1.338	− 3.95	+31.67	1
Do	San Francisco	39	+37.00	2.74	−0.33	1.322	− 3.62	+33.38	4
Dist. of Columbia	Washington	39	+ 2.85	7.33	−0.85	1.411	−10.34	− 7.49	4
Florida	Key West	39	+50.64	3.89	−0.41	1.332	− 5.18	+45.46	5
Georgia	Augusta	39	+16.97	5.45	−0.66	1.373	− 7.48	+ 9.49	5
Do	Savannah	39	+21.51	5.29	−0.65	1.371	− 7.25	+14.26	4
Illinois	Cairo	42	+ 0.26	7.09	−0.23	1.308	− 9.27	− 9.01	3
Indiana	Indianapolis	42	− 8.88	6.62	−0.13	1.296	− 8.58	−17.46	4
Iowa	Davenport	41	−15.02	6.53	0.00	1.282	− 8.36	−23.38	4
Do	Des Moines	35	−17.91	6.30	−0.21	1.306	− 8.23	−26.14	4
Do	Keokuk	42	−13.36	6.73	−0.17	1.302	− 8.76	−22.12	4
Kansas	Dodge City	39	−10.67	7.01	+0.02	1.279	− 8.97	−19.64	3
Kentucky	Louisville	41	− 0.88	7.29	−0.39	1.330	− 9.70	−10.58	2
Louisiana	New Orleans	39	+25.80	5.72	−0.99	1.440	− 8.24	+17.56	3
Do	Shreveport	39	+15.38	6.97	−0.67	1.375	− 9.58	+ 5.80	3
Maryland	Baltimore	43	+ 5.63	5.63	−0.76	1.390	− 7.83	− 2.20	4
Mississippi	Vicksburg	39	+16.90	6.36	−0.86	1.411	− 8.97	+ 7.93	3
Nebraska	North Platte	39	−18.69	8.35	−0.12	1.295	−10.81	−29.50	3
Do	Omaha	39	−16.10	6.77	−0.32	1.320	− 8.94	−25.04	4
New Jersey	Atlantic City	39	+ 3.62	5.58	+0.07	1.274	− 7.11	− 3.49	5
New Mexico	Santa Fe	39	− 2.46	5.56	−0.15	1.298	− 7.22	− 9.68	5
New York	New York	42	+ 1.95	4.79	+0.27	1.256	− 6.02	− 4.07	4
North Carolina	Wilmington	39	+17.08	4.82	−0.17	1.301	− 6.27	+10.81	5
Ohio	Cincinnati	43	− 2.28	6.25	−0.18	1.302	− 8.14	−10.42	4
Oregon	Portland	39	+16.67	7.37	−0.69	1.378	−10.16	+ 6.51	4
Pennsylvania	Pittsburgh	39	− 2.69	5.45	−0.68	1.377	− 7.50	−10.19	3
South Carolina	Charleston	39	+21.69	5.50	−0.81	1.380	− 7.59	+14.10	6
Tennessee	Knoxville	43	+ 4.14	8.43	−0.59	1.362	−11.48	− 7.34	5
Do	Memphis	39	+ 7.97	7.00	−0.36	1.327	− 9.29	− 1.32	4
Do	Nashville	39	+ 3.33	7.73	−0.15	1.299	−10.04	− 6.71	4
Texas	Galveston	42	+25.33	6.36	−0.44	1.337	− 8.50	+16.83	3
Utah	Salt Lake City	39	+ 0.05	6.72	−1.16	1.459	− 9.82	− 9.77	5
Virginia	Cape Henry	39	+14.59	4.74	−0.23	1.309	− 6.20	+ 8.39	5
Do	Lynchburg	39	+ 6.10	6.68	−0.23	1.308	− 8.74	− 2.64	7
Do	Norfolk	39	+13.64	5.12	−0.30	1.318	− 6.75	+ 6.89	5
Wyoming	Cheyenne	41	−18.71	7.78	−0.11	1.294	−10.07	−28.78	4

GRAPHIC METHOD OF REPRESENTING AND COMPARING DROUGHT INTENSITIES.[1]

By THORNTON T. MUNGER.

[U. S. Forest Service, Portland, Oreg., Nov. 1, 1915.]

It is a matter of interest among foresters to find a way for expressing in some graphic quantitative fashion the comparative forest fire risk of various years, and to determine the relative fire risk in various regions. There are so many factors that combine to create a fire hazard in our forests that it is difficult to express them in a statistical or graphic form.

The most influential meteorological factors are the infrequency of soaking rains, the total amount of rain in the dry season, the depth of the winter snow and the time of its disappearance, the humidity of the atmosphere, the frequency of very hot days, the occurrence of high winds, particularly of dry winds, and the seasonal temperatures as they affect the time at which the herbaceous vegetation matures and dries up. All these factors of precipitation, temperature, and wind movement are so complexly interwoven that it seems to be impossible to combine them and consider them jointly. The one single factor that has the most important influence on

[1] This method of showing drought severity was described by District Forecaster E. A. Beals at the meeting of the Western Forestry and Conservation Association on Dec. 7, 1914, using diagrams modeled after those originated by the author.

the fire hazard in the Pacific Northwest is the infrequency of soaking rains—i. e., the intensity of the droughts.[2] For a period of from 20 to 50 days in July and August there is, as a rule, practically no precipitation. It is this drought that dries out the forests so that fires become epidemic at this time, both their number and particularly their severity being closely related to the duration of the drought. To show the comparative severity of the summer droughts of several years, a table of their duration is not adequate, because their parching effect is not directly proportional to their length. It increases in geometric relation to the length of the dry period—thus a 30-day drought is much more than twice as intense as a 15-day drought. Let us assume that the intensity of droughts increase as the square of their duration, an arbitrary but probably fair assumption in the case of forest desiccation. On this hypothesis a 30-day drought would be four times as intense as a 15-day drought.

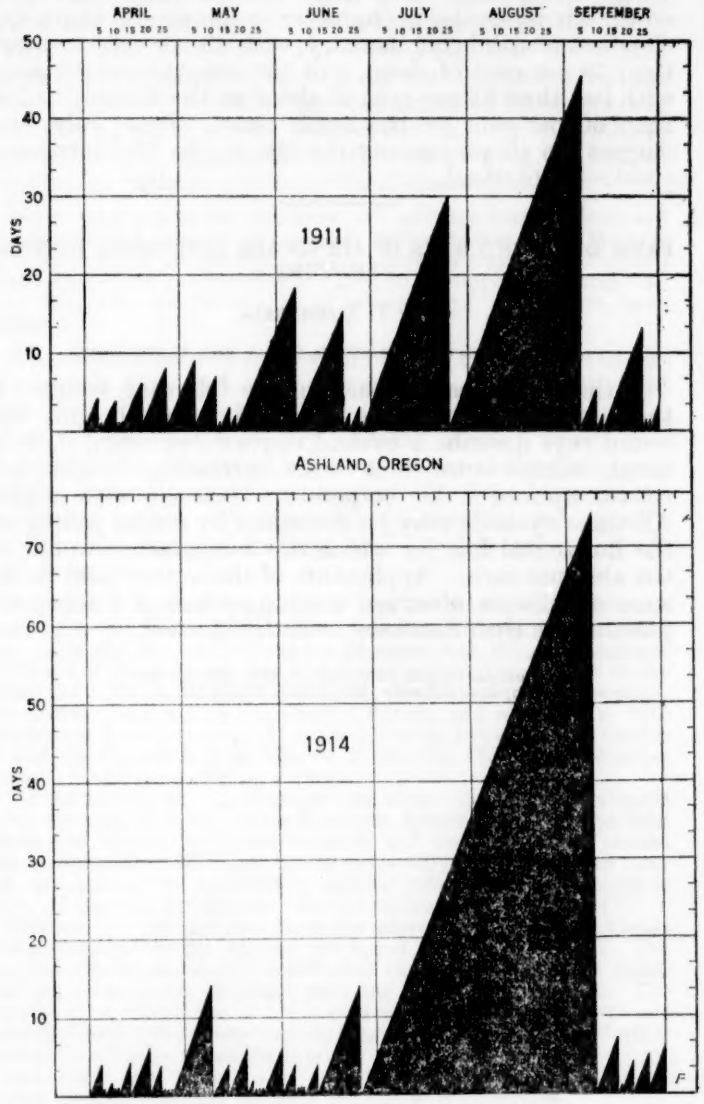

FIG. 1. Graphic representations of the drought intensities at Ashland, Oreg., during the summers of 1911 and 1914. Ordinates and abscissæ both represent duration of dry periods having less than 0.05 inch precipitation on any one day (midnight to midnight).

To present drought intensity graphically, using this hypothesis, a series of diagrams was drawn on coordinate paper, using the single variable the length of the period without a 24-hour rainfall of 0.05 inch. The intensity of the drought was represented by a right-angle triangle, whose height and base were both proportional to the duration of the drought. A set of these diagrams for two contrasting years is shown in figure 1. Whether or not the scale of the abscissæ and ordinates is equal, is immaterial. In these particular diagrams it was considered that any rain of 0.05 inch (in 24 hours) broke the drought. The righthand edges of the triangles therefore mark the dates on which rain fell to this amount or more.

The value of these diagrams is in showing at a glance the relative intensity of droughts in a series of years for any one place, and partly in showing the comparative drought intensity (or fire hazard) of various localities. This can be reduced to an absolute quantitative expression by actually measuring the areas of all the triangles in each year's diagram. The actual fire risk in the vicinity of Ashland, Oreg., judged by the experience of the Forest Service in fighting fire, was for the years 1911 and 1914 about as shown by the above sample diagrams.

Where it is not desired to show graphically the intensity of the drought, it may be computed directly by a formula first suggested by Mr. A. A. Griffin, viz—

$$\text{Severity of drought} = \text{length of drought} \times \tfrac{1}{2} \text{ length of the drought.}$$

Thus a drought of 30 days would have an intensity value of $30 \times \frac{1}{2}30 = 450$; while in the same period 5 droughts, one of 10 days and four of 5 days each, would have an intensity value of—

$$10 \times \tfrac{1}{2}10 + 5 \times \tfrac{1}{2}5 + 5 \times \tfrac{1}{2}5 + 5 \times \tfrac{1}{2}5 + 5 \times \tfrac{1}{2}5 = 100.$$

Using this formula (or actually measuring the areas of the triangles) the drought severity factor for Ashland, Oreg., is found to be 1,839 for 1911 and 3,206 for 1914. The average for the seven years, 1908–1914, is 2,142. Thus, the droughtiness of the year 1911 was 303 units, or 14 per cent, below the average, while the year 1914 was 1,064 units, or 49 per cent, above the average. Similarly a comparison of the average for various localities may be made.

Using the assumption that the intensity of a drought increases as the square of its duration, it is possible that this form of illustrating drought intensity might have a number of uses wherever the prolonged absence of precipitation is of economic importance—in agriculture, forestry, or in any industry affected by precipitation. By this method the distribution of the rainfall day by day could be most beautifully shown. The places with an evenly distributed rainfall would have an even-topped sawtooth diagram, the more frequent the rains the finer the teeth, while places with a long dry season would have a conspicuous high peak or two in the year's diagram.

Drought severity is so much more important in agricultural pursuits and in the prevention of forest fires than drought duration that a means of expressing it is needed. For educational purposes this method of showing comparative meteorological conditions is recommended because it is so graphic. It is thought that it also has practical value as a means of determining the normal year, the departures from the normal year, the relative conditions in various localities, and expressing these conditions in quantitative terms.

[2] The meteorological aspects of droughts, in comparison with their agricultural and other aspects, were clearly pointed out in this REVIEW, August, 1894, 22:393-394.—C. A., jr.

RELATION BETWEEN STRENGTH OF THE TRADE WINDS OF THE NORTH ATLANTIC AND TEMPERATURE IN EUROPE.[1]

By P. H. GALLÉ.

[*Reprinted from* Science Abstracts, Sect. A, Sept. 28, 1916, §994.]

In a former paper[2] it was suggested that the effect of a change in the North Atlantic trade winds could be traced after 2 or 3 months in some hydrographical phenomena of northern Europe, the action taking place through the intermediary of the Gulf Stream.[2] A further question arises as to whether the winter temperature of northwestern Europe will not also be found to have a connection with trade-wind agencies. The problem is attacked by the method of correlation, coefficients being calculated between the winter temperature—December to February—at many stations in a comprehensive area which embraces Europe and Iceland, and the strength of the North Atlantic trades in different periods of the preceding summer. The 15 years 1899–1913 are used for the purpose. Taking Europe as a whole, it is found that the period May to October for the trades gives the highest correlation with European winter temperatures, June to November giving only slightly less. The values for the individual stations have been plotted on maps and lines of equal correlation drawn. It is found that positive departures from normal in the strength of the northeast trade are accompanied by positive departures of the winter temperature at places to the southeast of a line passing through the British Isles and central Norway and by negative temperature departures to the northwest of this line. The positive coefficients range up to +0.7 and the negative to −0.6. In considering what degree of accuracy could be obtained in forecasting the temperature of a coming winter from knowledge of the strength of the trades in the previous summer, the region which shows the highest correlation (central Germany) is chosen, and the deviations from the normal of the two elements are plotted on the same diagram for 16 years. It is found that in 14 cases out of the 16 the deviations show the same sign, and thus it would have been possible in 7 out of 8 cases to make a good forecast about the sign of the departure of the coming winter temperature. The standard deviation of the temperature is 1.3 degrees (C.), and, making use of the trade-wind strength, the error of estimate of the temperature will be 0.5 degree (C.).—*J. S. Di*[*nes*].

[1] Proc. K. Akad. Amsterdam, 1916, 18 : 1435–1448.
[2] See abstract in this REVIEW, July, 1915, 43 : 341.

MONTHLY DISTRIBUTION OF MEAN CLOUDINESS OVER FRANCE.[3]

By G. BIGOURDAN.

[*Reprinted from* Science Abstracts, Sect. A, Sept. 28, 1916, §991.]

This gives 13 charts showing the mean distribution, expressed in percentages, of the proportion of the sky covered with cloud for the 12 months and the whole year. On the average of the months, the Mediterranean coast has less than 35 per cent of cloud, and cloudiness increases with latitude generally up to about 65 per cent on the north coast of France. There are secondary maxima of cloud over the Pyrenees and the Jura and Vosges Mountains. The individual monthly charts are, on the whole, similar in character to the annual chart, the cloudiest month being January, with 40 per cent to more than 70 per cent of cloud, and the sunniest month July, with less than 25 per cent of cloud on the Riviera to less than 60 per cent on the north coast. June, July, and August are all very sunny months on the Mediterranean coast.—*R. C*[*orless*].

PATH OF SOUND RAYS IN AIR UNDER INFLUENCE OF TEMPERATURE.[4]

By V. KOMMERELL.

[*Reprinted from* Science Abstracts, Sect. A, Sept. 28, 1916, §1055.]

A theoretical paper reaching the following results: If the temperature changes uniformly with height, the sound rays describe a cycloid convex downward if, as is usual, temperature falls with increasing height; but convex *upward* if the temperature increases with height. All these cycloids may be described by circles rolling on the horizontal line for which the temperature would be the absolute zero. Application of these principles to the zone of silences observed around sources of intense explosions are then discussed.—*E. H. B*[*arton*].

[3] Comptes rendus, Paris, Apr. 25, 1916, 162 : 620–625.
[4] Physikal. Zeitsschr., May 1, 1916, 17 : 172–175.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR NOVEMBER, 1916.

EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Washington, D. C., Dec. 22, 1916.]

Of the LOWS that appeared on the weather maps of the United States during November, six were of the Alberta type, five the North Pacific, one South Pacific, one the Northern Rocky Mountain region, two Colorado, and one of tropical or West Indian type. In all there were 17 and there was no uniformity with respect to their speed and direction of movement.

Of the HIGHS that made their appearance during November, 14 in number, 2 first appeared over the western Canadian Provinces, 4 over the Rocky Mountain region, 2 off the North Pacific coast, 4 off the South Pacific coast, and 2 north of the Great Lakes and St. Lawrence Valley. The most important of the HIGHS was that which appeared over Alberta, Canada, on the 10th and advanced thence in a southeasterly direction attended by severe cold in nearly all parts of the United States. On the 9th, in advance of the appearance of this cold wave, the following special bulletin was issued and disseminated:

Disturbance now in the Northwest will advance southeastward and be followed by a pronounced change to colder weather within the next 36 to 48 hours in the northern Rocky Mountain region and Northern Plains States, and by Saturday the 13th, in the upper Mississippi Valley. The cold weather will be of several days' duration in these regions.

The disturbance of most pronounced character was the one which appeared in the southwest on the 20th and 21st and moved northeastward across the Great Lakes where it was attended by shifting gales. Whole-gale warnings were displayed well in advance of the dangerous winds, and as a result no marine disasters occurred on the Great Lakes. Commenting on the warning, an editorial in the Times of Buffalo, N. Y., of December 1, reads as follows:

Now that navigation is practically over for the season of 1916, one looks back with pride to the enormous amount of traffic on the inland seas. Considering the few marine disasters and the comparatively small loss of life in connection with handling the gigantic fleet on the Great Lakes during the past season, one can but commend the excellent service rendered by the Weather Bureau, and especially so with reference to the severe storm that passed over the Lake region November 23 and 24, for which Prof. Charles F. Marvin, Chief U. S. Weather Bureau, issued the following warning:

"WASHINGTON, D. C., *November 23, 1916.*—Change to whole-gale storm warning, 10 a. m., Lakes Michigan, Huron, and Erie, and hoist whole-gale warning on Lakes Superior and Ontario. Storm central over southern Lake Michigan increasing rapidly in intensity and moving northeast will be attended by shifting gales and rain, changing to snow. Dangerous conditions. Advise vessels to remain in port."

This was the first instance since the adoption of the Beaufort scale that a whole-gale storm warning was issued for the Lake region. The warning was so thoroughly distributed throughout the Great Lakes that not a vessel left port until after the severe gale subsided. The absence of wrecks or loss of life is evidence that the marine interests generally heeded the strong warning issued by the Chief of the Weather Bureau for all ships to remain in port.

And this is only one of many instances where the Weather Bureau, during the past year, has rendered the public great service.

The Free Press of Detroit, Mich., of November 26, stated:

Vessel men in Detroit and in other lake ports were congratulating each other Saturday over the fact that there apparently was no loss of life or vessel property in the severe gale that beat the lakes Thursday and Friday, with the one exception of the new Standard Oil Company barge *No. 82*, which was wrecked Friday on Grenadier Island, Lake Ontario, near Kingston, Ontario, after her anchor chain parted.

To the general observance of safety first principles rather than to any favoring of daring navigators by good fortune, is credited the fact that the lake fleet seems to have come through the hurricane period unscathed and without decimation.

The circumstances, previously deplored, that many of the freighters were being held in ports at the head of the lakes by slow loading of frozen ore, and in ports on Lake Erie by shortage of cars for handling their cargoes, may have been an important factor in averting perils for many of the vessels, as it was possible to immediately inform them of *threatening atmospheric conditions, when the Weather Bureau gave warning of the approach of a storm of full-gale intensity, Thursday forenoon.*

Others were warned by radio stations. A large number of ships in transit were held in the rivers above and below Lake Huron to await developments. As many as 27 were counted in Detroit River Friday, while 44 were lying in the vicinty of Port Huron and other large fleets lay above and below Sault Ste. Marie, in the straits of Mackinac and in various other sheltered spots.

With all the crowding of freighters in Detroit River, only one accident was reported. The new Norwegian steamer *Thorngerd*, just completed at Port Arthur and on her way to the Atlantic without cargo, swung in the channel near Grassy Island and stuck her stern on the bank. She was pulled off early Saturday morning by the tug *A. W. Colton* of the Great Lakes Towing Co., and was reported passing down through Lvingstone channel about 6:30 o'clock Saturday night.

The tropical disturbance referred to made its appearance on the 12th over the Caribbean Sea east of Honduras, moved thence in a northwesterly direction through the Yucatan Channel; it recurved over the southeastern portion of the Gulf of Mexico and advanced northeastward over extreme southern Florida during the 15th and passed eastward over the Bahamas. This disturbance, according to press reports, did considerable damage to property along the coast of Honduras and in Yucatan.

GENERAL PRESSURE DISTRIBUTION.

Over the Alaskan area the pressure was below the normal at nearly all stations from the 1st to 7th, decidedly above the normal during the 8th to 13th, and below the normal thereafter to the end of the month except from the 21st to 24th, inclusive. In the vicinity of the Hawaiian Islands the pressure was above the normal from the 1st to 8th, and 16th to 28th, inclusive, and below the normal at other times during the month. In the vicinity of Bermuda, the pressure was below the normal during the 1st to 4th, and 16th to 20th, inclusive, and above the normal on all other days during the month.

DISTRICT WARNINGS DURING NOVEMBER.

Washington district.—At the beginning of the month the pressure was low over the western Caribbean Sea and high in the Atlantic States, a condition that persisted during several days, but no well-defined disturbance developed within the area of low pressure over the Caribbean Sea. Advisory notices of strong winds, however, were necessary for the Florida Straits and adjacent waters. The night of the 5th, when a disturbance of marked intensity was central north of Montana, advisory information to the effect that strong southerly winds would prevail was sent to stations on the Upper Lakes and storm warnings were displayed on western Lake Superior, and on the morning of the 6th the display of warnings was extended to cover Lakes Michigan, Huron, and eastern Lake Superior. The disturbance moved northeastward toward Hudson Bay attended by strong southerly winds on the upper Lakes, but they were not of sufficient force to interfere with navigation.

On the 7th a disturbance made its appearance over the southern Rocky Mountain region and moved northeastward, crossing the Great Lakes on the 8th and 9th. Advisory information covering this disturbance was sent

to Great Lakes stations on the 7th and later southwest storm warnings were ordered for the lower Lakes, where winds of moderate gale force occurred on the 9th.

The disturbance over the Great Lakes moved down the St. Lawrence and the morning of the 9th southwest storm warnings were displayed on the Atlantic coast at and north of Delaware Breakwater; the display was followed by south to west gales during the afternoon and night of the 9th over the region where warnings were displayed. This disturbance was followed quickly by a secondary disturbance on the Great Lakes, and the afternoon of the 10th southwest storm warnings were again displayed on Lakes Erie and Ontario and were followed by westerly gales during the night of the 10th. The highest velocity, 68 miles an hour, occurred at Buffalo, N. Y.

On the 8th and 9th announcements were made of fresh easterly gales for the Yucatan Channel, Cuban waters, and the southeastern portion of the Gulf of Mexico, when, strong pressure gradients were in evidence in these regions, and there were indications of a disturbance to the west of Jamaica. The winds of gale force occurred as forecast, but the disturbance over the Caribbean Sea did not gain more than moderate intensity.

On the evening of the 11th when there were some indications of the development of a disturbance in the central Mississippi Valley, northeast storm warnings were displayed on Lakes Michigan and Huron, and during the 12th and 13th strong easterly winds and snows occurred on these lakes, although at no station did the wind reach gale force.

Reports from the West Indies on the 13th showed unmistakable signs of a disturbance over the western Caribbean Sea and information was issued as follows:

> Hoist northeast storm warning 10 a. m., southern Florida coast, Tampa to Jupiter Inlet. Disturbance central in the vicinity of Swan Islands, increasing in intensity, will move northward attended by strong shifting winds, probably of gale force over the east portion of the Gulf of Mexico, southern Floridan, and Cuban waters.

The afternoon of the 13th northwest storm warnings were displayed on the gulf coast from Bay St. Louis, Miss., to Cedar Keys, Fla. The tropical disturbance moved northward as forecast and reached the east Gulf of Mexico the morning of the 15th, where it recurved and passed northeast across the Florida Peninsula during the afternoon of that day. This disturbance was attended by gales over the Gulf of Mexico and adjacent waters, the highest velocities reported being 52 miles an hour at Key West and 64 miles an hour at Habana during the night of the 15th, and also off the Atlantic coast as far north as Cape Cod. Shipping in the regions where the gales occurred was fully advised concerning the expected gales, and so far as known no wrecks occurred.

The disturbance of greatest intensity to influence weather conditions in the Washington district in November was of the Texas type and formed in the Rio Grande Valley. Its center on the morning of the 22d was over Arkansas, on the morning of the 23d over Lake Michigan, and on the morning of the 24th over the St. Lawrence Valley. Storm warnings were displayed in connection with this storm on the Great Lakes and on the Atlantic and east gulf coasts and winds of gale force occurred generally over the regions where warnings were displayed. On the morning of the 23d when the center of this disturbance was over southern Lake Michigan, the storm warnings already displayed were changed to "whole gale or hurricane" warnings, and subsequently the Great Lakes were subjected to gales and snow that arrested navigation generally, yet because of the timeliness of the warnings no loss of shipping occurred on any of the Lakes.

Southwest storm warnings were displayed on the lower lakes on the 26th when a disturbance was central near Lake Superior, and, while strong winds occurred on these lakes and on Lakes Michigan and Huron, the storm was not dangerous.

Frost warnings were issued on a number of days for the east Gulf States and the Florida Peninsula, except the extreme south portion, and in nearly all instances frosts or freezing temperatures occurred as forecast. There was but one cold wave of importance during the month in this district. It made its appearance in the Northwest on the 10th and 11th and advanced thence eastwardly and overspread the region east of the Mississippi River during the 13th to 16th. Cold-wave warnings were ordered well in advance of this cold change which carried the line of freezing temperature southward to the middle Gulf coast and northern Florida.

Chicago district.—The first cold-wave warnings of the season were issued on the 9th. The morning reports of that date showed a marked decrease in pressure throughout the Northwestern States and a decided increase over Alaska and southeastward to British Columbia, indicating that the disturbance then centered just north of Montana would move rapidly southeastward and be followed by a strong area of high pressure from Alaska.

A forecast of "much colder" was incorporated in the regular morning forecasts for all States west of the Mississippi River, except Missouri, the period being entended to cover 48 hours in most cases. In addition, the central office issued a special forecast covering a pronounced fall in temperature expected in the trans-Mississippi region within the next 48 to 60 hours and stating that the cold weather would continue for several days. While the p. m. reports of the 9th did not show any low temperatures in the western Canadian Provinces, the 12-hour changes in pressure were such as to indicate a decided fall within the next 24 hours throughout the Northwest. Accordingly, cold-wave warnings were issued for Wyoming, eastern Montana, the Dakotas, and the northwestern portions of Minnesota and Nebraska. The following morning warnings were extended to include the remainder of Minnesota and Nebraska, except entreme southeastern Nebraska, northwestern Iowa, and western and central Kansas, the remainder of Kansas being included in warnings issued on the night of the 10th. These warnings were fully verified, except in the eastern portions of Kansas and Minnesota and northwestern Iowa. The cold wave gradually increased in severity in the northern Rocky Mountain region and Northeastern Slope until the morning of the 13th, when the lowest November temperatures of record were registered in Wyoming and western South Dakota, Sheridan, Wyo., reporting a minimum of $-26°$F.

The only other warnings during the month were issued on the morning of the 23d. A disturbance of marked intensity was centered near Chicago moving northeastward, while a high-pressure area of considerable strength was advancing southeastward over British Columbia and Alberta, although no low temperatures were reported, except at Kamloops and Barkerville. Inasmuch as both the storm and the high-pressure area were expected to gain in strength, cold-wave warnings were issued for eastern Montana, Sheridan, Wyo., North Dakota, northern South Dakota, and northwestern Minnesota. The warnings were verified, and in addition, verifying temperatures were reached in southwestern South Dakota and northwestern Nebraska.

The great value of regular reports from Barkerville, Triangle Island, and Prince Rupert in connection with forecasts and warnings issued for the northern Rocky

Mountain region and northwestern States was specially emphasized on both occasions when cold-wave warnings were issued for those States during November.—*Chas. L. Mitchell, Assistant Forecaster.*

Denver district.—The month was marked by unusual conditions. Instead of the practically stagnant pressure distribution so common in November, the month was characterized by a rapid succession of high and low pressure areas, remarkably low temperatures in practically all parts of the district and much more than the usual variability in temperature. On the morning of the 10th a low-pressure area was central in eastern Colorado, with loops of the depression extending northwestward over Wyoming. High pressure overlay Montana and the Canadian Northwest, but there were no indications of the development of unusual cold, nor of the filling in of the western part of the low pressure in the central Rocky Mountains. During the following 12 hours the increase in intensity and magnitude of the anticyclone was marked and temperatures continued falling throughout northern districts. Cold-wave warnings were issued for eastern Colorado, it now being clear that the front of the anticyclone would move southward along the eastern Rocky Mountain slope. The warnings were fully verified. On the morning of the 11th warnings for southeastern Colorado were repeated together with warnings for northeastern New Mexico. The warnings were verified. On the morning of the 12th low pressure still occupied western Colorado, western New Mexico, and Arizona, and 12 hours later the LOW was central in western New Mexico. Cold-wave warnings were issued for southwestern Colorado, northern and eastern New Mexico, and northeastern Arizona, despite the fact that the eastward movement of the depression was blocked by the anticyclone on the southeastern slope. The warnings were fully verified, except in extreme southwestern Colorado. At Grand Junction the temperature reached 6°F., the lowest of record for November. Beginning with the morning of the 13th and continuing till the 29th warnings of frost for south-central and southeastern Arizona were issued almost daily. During the greater part of this period a ridge of pressure overlay New Mexico and the region northwestward. Frosts and freezing temperatures were of practically daily occurrence in this part of Arizona.—*Frederick H. Brandenburg, District Forecaster.*

New Orleans district.—Small-craft warnings were issued on November 7 for the Texas coast and on November 8 from Galveston to Corpus Christi, Tex., because of a depression of more than moderate intensity, moving from New Mexico eastward over Texas. The warnings were justified.

On November 8, a trough of low pressure, extending southwestward from the lake region to Texas, was attended by high temperatures over most of the district. An area of high pressure was central over the middle Pacific Coast States and the Plateau region, preceded by abnormally low temperatures. Freezing was forecast for northwestern Oklahoma and the Texas Panhandle and frost in the northern and western portions of western Texas. The warning was completely verified, temperatures of 30° to 34°F. prevailing over the area indicated.

Freezing temperatures were forecast for the northwestern portion of the district on November 9 but failed because of the rapidly developing depression from western Canada, which on November 10 formed a trough of low pressure over the upper Mississippi Valley and the southern Plains States.

On the morning of November 10, a cold-wave warning was ordered for the Texas Panhandle because of a high pressure area of considerable magnitude over British Columbia. This warning was verified, the temperature at Amarillo falling from 52° at 8 p. m. on November 10 to 24° at 8 p. m. on the 11th. The anticyclonic area moved southeastward, attended by very cold weather over the northern Rocky Mountain region, with a steep pressure gradient southward to an area of low pressure over the southern Rocky Mountain region. At 8:20 p. m. on the 10th cold-wave warnings were ordered for western Oklahoma and were repeated the next morning and extended to include northeastern Oklahoma and the extreme northwestern portion of east Texas. Freezing weather was forecast for Oklahoma, northern and western Arkansas, and northwestern Texas as far as Abilene. The cold area did not advance with sufficient rapidity to cause freezing in Arkansas, but freezing weather prevailed on the morning of November 12 over nearly all of the remainder of the indicated area. The cold-wave warning for Oklahoma and the extreme northwestern portion of East Texas, and a cold-wave warning issued on the 8 p. m. map of the 11th for Fort Worth and Dallas, failed of complete verification because of the slow southeastward movement of the cold area. The high-pressure area continued to move southeastward on the 12th and 13th, but not rapidly enough to verify frost warnings for the interior of Louisiana nor for the greater portion of Arkansas; but freezing temperatures were recorded in eastern Oklahoma.

Cold-wave warnings were ordered on the morning of the 13th for Palestine, Tex., and southern Texas, except the extreme west coast. Freezing weather was predicted to extend also to northern and central Arkansas, and northwest storm warnings were issued for the Galveston section. Special observations, which were called for, showed that the high pressure area was beginning to move more rapidly, and at 1:40 p. m. on the 13th cold-wave warnings were issued for Louisiana and eastern and southern Arkansas, while the northwest storm warnings were extended to include the entire Texas coast. The sugar and trucking interests of Louisiana were warned to expect freezing temperatures by the morning of Wednesday the 15th, and these warnings were made emphatic and given wide distribution. The warnings issued on this date were successful. Northwest storm warnings were ordered for the Louisiana coast on the 13th at 9 p. m. and were ordered continued on the 14th, and were fully justified by conditions off the middle Gulf coast.

The cold-wave warning for Louisiana was repeated at 8:30 p. m. on the 13th and for southeastern Louisiana at 9 a. m. on the 14th—temperatures of 22° to 26° in the northern portion of the sugar and trucking region and 26° to 30° in the southern portion being forecasted to occur on the following morning. The cold-wave and temperature forecasts were verified, and the warnings enabled sugar growers to save most of their seed cane and to expedite windrowing. Because of the warnings a large amount of sugar cane was cut before the freeze and much of the matured truck was gathered. Temperatures of 24° to 30° were predicted for the sugar and trucking region of Texas, and were generally attained. The southern portion of the high-pressure area was over Texas on November 15, and it was necessary to repeat the low-temperature predictions for Louisiana and to give warnings of freezing in the sugar and trucking region of southern Texas. These forecasts were successful, temperatures being in some places in Louisiana 1 or 2 degrees lower on the morning of the 16th than on the preceding morning. Frost to the coast was forecast on the 16th for Louisiana, and the warning was justified.

With high pressure and cool weather over the southwestern portion of the country on the 18th, frost to the coast in Louisiana, and frost nearly to the coast in east Texas were forecast and conditions on the following morning showed that the warnings were justified.

The temperature was high in Arkansas on November 21 and an area of high pressure over the Rocky Mountain region threatened much colder weather. The low pressure area, however, which was developing over southern Texas, gained unexpected strength on the following day and extended its influence farther westward than was anticipated, and a cold-wave warning ordered for Bentonville, Ark., failed of verification. Freezing was predicted for Oklahoma and the northern portion of western Texas but the temperatures did not reach freezing in eastern and southern Oklahoma.

On account of the development of the disturbance over southern Texas, as indicated by the 8 p. m. map of the 21st, northwest storm warnings were ordered on the Texas coast. The winds increased but did not reach gale velocity. The disturbance was over the lower Mississippi Valley on the 22d and conditions on the Louisiana coast, as shown by a special observation from Burrwood, were such as to make advisable a small-craft warning ordered at 2:15 p. m.

On November 22 and 23, with a high pressure area moving eastward over the Rocky Mountain region and extending southward over Texas, frost was predicted for the southern portion of east Texas nearly to the coast and frost temperatures were recorded. On the 24th, freezing nearly to the coast and temperatures of 30° to 34° in the sugar and trucking regions were forecast for southern Louisiana and southeastern Texas. Predicted temperatures occurred in the Louisiana sugar and trucking region, and the conditions in Texas were evidently similar. Freezing temperatures, or lower, occurred generally in other portions of the forecast district as predicted.

On November 25, heavy frost to the coast, with temperatures of 28° to 32° in the sugar and trucking region of Louisiana, and frost in the southeastern portion of eastern Texas nearly to the coast, were successfully predicted. On the 30th was forecasted frost to the Louisiana coast and in the southeastern portion of eastern Texas except in the lower Rio Grande Valley and on the coast, and occurred as predicted.

On November 3 a special forecast of fair weather for the three following days was issued at 8:20 p. m. for the Shreveport State Fair, and was verified.

Fire-weather warnings were issued for western Oklahoma on the 5th, 8th, 11th, 13th, 21st, and 26th, and for Arkansas on the 5th, 6th, 7th, 8th, 11th, 13th, and 27th. They anticipated wind velocities of more than 15 miles an hour, with a statement of the wind direction and character of weather indicated. In some cases these warnings were for a period of 48 to 56 hours but most were for the following day. Conditions occurred generally as forecast except that in a few instances the weather forecasts were not verified.—*R. A. Dyke, Assistant Forecaster.*

Portland (Oreg.) district.—November opened with a low-pressure area over Alaska, causing rains in western Washington that gradually overspread the district and continued quite generally, until the 9th when clearing weather set in due to the southeastward advance of an extensive high pressure area from northern Alaska. On the night of the 10th–11th, this HIGH lay over the eastern slope of the northern Rockies and the Plains States, and an unusual fall in temperature occurred over the Northwest. Killing frosts occurred on the Washington coast on the mornings of the 11th and 12th, and the lowest temperatures of record were reported from southern Idaho from the 11th to 13th, and from the Umpqua Valley, Oreg., on the evening of the 12th. This drop in temperature reached the proportions of a cold wave over southern Idaho, a 24-hour fall of 36° having occurred at Pocatello by the morning of the 11th. The meteorological conditions preceding the cold wave were not expected to cause such a decided temperature fall, for it was thought that northeast winds crossing the Rocky Mountains and heating slightly adiabatically would prevent a marked fall, but the extent and intensity of the HIGH were underestimated. A portion of the high pressure area, with attendant low temperatures, settled over the inter-montane region and fair weather with cold easterly winds continued until the 22d, broken only on the 18th when rains fell generally west of the Cascade Mountains and rain or snow in eastern portions of Oregon and Washington. A moderate cold wave forecasted for the 23d did not occur due to the effect of a rapid decrease in pressure along the North Pacific coast—the greatest 24-hour temperature fall reported having been 12° at Baker, Oreg. On the 28th a high-pressure area moved rapidly from the southern Oregon-California coast to the Plateau region and unusually rapid radiation caused a close approach to a cold wave over southeastern Idaho, for which cooler weather had been forecast.

Precipitation occurred in many portions of the district from the 25th to the 28th; a heavy fall occurred west of the Cascade Mountains.

General storm warnings were ordered on the 3d, 4th, 5th, and 27th, two were fully verified, one partially, and the one on the 5th was not. Warnings for part of the coast were ordered on the 2d, 9th, 17th, 21st, 24th, 26th and 29th; three were partially verified, and those on the 9th and 17th were not. Verifying wind velocities occurred on the 1st at North Head and Tatoosh Island, on the 8th at Seattle and Tacoma, and on the 21st at Seattle, without warnings having been issued, but we have learned of no resulting damage. Small-craft warnings were issued on the 5th, 8th, 14th, 15th, 16th, 17th, 21st, 25th, and 29th, all justified.

Frost warnings were not issued during November.—*T. Francis Drake, Assistant Forecaster.*

San Francisco district.—Southeast storm warnings were ordered from Point Reyes to Eureka on the 5th and 25th, and were partially verified.

The feature of the month was the period of cold weather with freezing temperatures and killing frosts from the 13th to 18th. Warnings of killing frost were issued on the morning of the 12th, and daily thereafter during the cold period. In some sections the growers were not prepared to protect their crops and serious injury resulted. The greatest damage occurred in the lower Sacramento and San Joaquin valleys, where minimum temperatures of 22° and 23° occurred. On the mornings of the 13th–15th, the temperature remained below 30° F. for several hours, and it was at this time that the greatest damage was done. In many sections vegetables and olives were killed and in some, citrus fruit experienced a heavy loss. The citrus groves located on the sidehills and where free air drainage obtained, experienced but little or no damage, while the groves in the low flat lands met with severe loss.—*G. H. Willson, District Forecaster.*

A special chart showing the hurricane tracks of the season of 1916 will appear in the December issue of the MONTHLY WEATHER REVIEW.

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, NOVEMBER, 1916.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau, Washington, Jan. 2, 1917.]

The year 1916 came to a close without floods of any consequence during the months of October and November. The precipitation of October and November was not sufficiently intense nor so widely distributed as to produce high stages in the streams.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

SIX YEARS OF SNOWFALL MEASUREMENTS IN THE CARSON, WALKER, AND TRUCKEE WATERSHEDS.

By H. F. ALCIATORE, Meteorologist.

[Dated: Weather Bureau Office, Reno, Nev., Sept. 23, 1916.]

The chief object of this paper is to show in what manner and to what extent the seasonal snowfall decreases in the watersheds of the Carson and Walker Rivers, as compared with the snowfall in the Truckee Basin. Thus we lay a foundation for correlating the available data on precipitation over the two watersheds first mentioned; with the stream-flow measurements made by the Government at stations located near their headwaters, and may be able eventually to predict their respective run-offs from our knowledge of the snowfall percentage relationships thus established.

In view of the fact that complete snowfall records are available for only a few Weather Bureau mountain-snowfall stations in these districts, no *quantitative* values as to the entire snow cover could be computed. By carefully scrutinizing and summarizing the data given in Tables 1–3 we can get a fairly accurate notion of the relative or percentage distribution of the precipitation in the several watersheds.

Some data as to altitude and depth of snow may prove of interest to the student.

In 1915 the author worked out a percentage relationship between the snowfall and run-off for the Tahoe Basin which has enabled us to forecast the run-off in Lake Tahoe for the season of 1916; therefore it seems reasonable to expect that whenever stream-flow data for the Carson and Walker Rivers become available we may do the same for those streams.

The snowfall values given below are of the kind which J. E. Church, jr., properly has termed "symptomatic." For example, in the Tahoe Basin the average snowfalls for the seasons of 1910–11 and 1911–12 were 320 and 150 inches, respectively. Regardless of such other considerations as water content, relative density, watershed areas, etc., there can be but one logical deduction from a comparison of these values, namely, that the first-named season was one of very heavy snows while the second was a very dry season. The percentages given also help in contrasting the two seasons.

The stations selected for this study are representative ones in so far as any choice was permissible, and the region within which they are situated is a quadrilateral in the Sierra Nevada about 49 by 56 miles, whose northern limit lies in latitude 39° 10′ N. and the eastern limit in longitude 119° 14′ W. Three of the stations—Tahoe, McKinney, and Bijou—are on the shores of Lake Tahoe; Marlette Lake, the highest station (7,900 feet), is on the southern shore of the small lake in Nevada bearing that name; the lowest station, Shields ranch (5,300 feet), is but a short distance west of the Nevada-California boundary.

The seasonal snowfall in the three watersheds is strongly contrasted by means of Table 1. The depth of the snow cover decreases rapidly as we travel southward from the Tahoe watershed, as plainly indicated by the six and seven year averages given in Table 1.

The greater elevation of the Tahoe basin, and the presence therein of a large lake which never freezes over, would account in a large measure for the relatively heavier snows in that region. It seems that in the case of the Carson and Walker Basins, however, some factor other than a difference of altitude must be the controlling influence that causes a markedly smaller snowfall in the Walker Basin, since the average elevation of the latter is the greater by some 320 feet. This factor evidently is both geographic and climatic, for the Walker Basin lies farther to the east and south, and the annual isohyets for eastern California and for Nevada plainly show that normally there is a considerable diminution of precipitation eastward from the summit of the range at all points in the same latitude. Again, the Walker watershed is farther away from the normal path of the Pacific coast cyclonic system.

It is noteworthy that during the last six years the minimum snowfall for that period was recorded in all basins in the same season, namely, that of 1911–12. No such uniformity of distribution, however, is disclosed as to the maximum amounts of snowfall; the season of deepest snows in the Tahoe watershed was that of 1910–11, and in the other watersheds, that of 1915–16. Comparing the "per cent of average" values given in Table 1 with one another, we note a wide variation in the snowfall percentage relationships between the several basins. In some seasons the snow was *relatively* heavier in the Walker Basin, and, in other seasons, lighter than in the Tahoe Basin, from which fact we are tempted to make the deduction, namely, that these variations were due to northward and southward deflections of the Pacific coast barometric depressions, from the normal storm path, in different seasons.

The question, How does the snowfall at different points in the same climatic zones increase with elevation? is of general interest. We have made some computations, the results of which are given in Table 2. The stations chosen for comparisons, as grouped, do not differ very much as to latitude, and have much in common as ot climate, as modified, of course, by altitude.

The snowfall in the Walker and the Truckee-Tahoe watersheds increases with altitude at the rate of about 18 inches for every 100 feet increase in elevation; from Reno to Summit the rate is slightly less, but from Truckee westward it is slightly over 18 inches. On the west slope

of the Sierras conditions are quite different; the rate of increase, from Fordyce Dam to Summit drops to 4 inches for every 100 feet of increase in elevation, or about 22 per cent of the rate for the east slope of the range. This remarkably small rate of increase in snowfall may be due to the fact that both Fordyce Dam and Summit are on the windward, or wet side on the mountains; at any rate, no better explanation suggests itself to the writer at the present time. Similar comparisons of increase of snowfall with altitude for other parts of the United States would doubtless prove very interesting to students of meteorology.

The distribution of the seasonal snowfall *by months* is shown in Table 3. As a rule, the heaviest snows occur in all watersheds in January. During the first three months of the season we may expect about 81 per cent of the total snowfall in the Truckee-Tahoe Basin; 84 per cent in the Carson, and 84 per cent in the Walker Basins. It will be seen that so far as run-off is concerned, the snows of the latter half of the season are of but little consequence, particularly the snowstorms of April and May. Not only is the snow less deep in the southern basins, but it disappears earlier than in the Truckee-Tahoe Basin.

TABLE 1.—*Comparative snowfalls in the Tahoe, Carson, and Walker watersheds, 1909–1916.*

STATIONS OF THE THREE BASINS.

Tahoe Basin:
Tahoe, Cal. (6,230 feet).
McKinney, Cal. (6,230 feet).
Marlette Lake, Nev. (7,900 feet).
Bijou, Cal. (6,230 feet).
Carson Basin:
Markleeville, Cal. (5,525 feet).
Woodfords, Cal. (5,634 feet). } Close to headwaters.
Walker Basin:
Bridgeport, Cal. (6,500 feet).
Shield's Ranch near Coleville, Cal. (5,300 feet). } Close to headwaters

[Seasonal snowfalls, Dec. 1 to May 31, incl.]

Season.	Tahoe Basin (4 stations).		Carson Basin (2 stations).		Walker Basin (2 stations).	
	Mean.	Per cent of average.	Mean.	Per cent of average.	Mean.	Per cent of average.
	Inches.		*Inches.*		*Inches.*	
1909–10			86	80.4	50	78.1
1910–11	320	137.3	144	134.6	94	146.9
1911–12	*150*	*64.4*	*62*	*57.9*	*39*	*60.9*
1912–13	203	87.1	78	72.9	40	62.5
1913–14	232	99.6	102	95.3	54	84.4
1914–15	190	81.5	120	112.1	53	82.8
1915–16	304	130.5	160	149.5	122	190.6
Average	233		107		64	

TABLE 2.—*Increase in snowfall with elevation.*

Stations and basins.	Altitude.	Distance between stations and direction.	Average annual snowfall.	Increase of snowfall with elevation.
Walker Basin:	*Feet.*	*From Shields Ranch.*	*Inches.*	*In./100 ft.*
Shields Ranch, Cal.	5,300		37	18
Tamarack, Cal.	8,000	18 miles W.	521	18
Truckee and Tahoe Basins:		*From Summit.*		
Reno, Nev.	4,532	25 miles NE.	30	16
Boca, Cal.	5,535	14 miles NE.	152	18
Truckee, Cal.	5,818	8 miles E.	195	19
Summit, Cal.	7,017		420	19
Sacramento and Yuba Basins:		*From Fordyce Dam.*		
Fordyce Dam, Cal.[1]	6,500		402	4
Summit, Cal.	7,017	9 miles SE.	420	4

[1] Fordyce Dam, Cal., is in latitude 39° 23′ N., longitude 120° 29′ W.

TABLE 3.—*Monthly snowfalls.*

Watershed.	December.	January.	February.	March.	April.	May.
Truckee-Tahoe:						
Average snowfall (inches)	33	116	37	29	13	5
Percentage of seasonal	15	50	16	12	5	2
Carson:						
Average snowfall (inches)	13	55	23	10	4	2
Percentage of seasonal	12	51	21	10	4	2
Walker:						
Average snowfall (inches)	11	28	15	7	2	1
Percentage of seasonal	17	44	23	11	3	2

MEAN LAKE LEVELS DURING NOVEMBER, 1916.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Dec. 5, 1916.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during November, 1916:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	603.50	580.64	571.70	245.65
Above or below—				
Mean stage of October, 1916	−0.22	+0.08	−0.20	−0.41
Mean stage of November, 1915	+0.69	+1.16	+0.25	+0.71
Average stage for November, last 10 years	+1.07	+0.49	−0.06	+0.13
Highest recorded November stage	−0.01	−2.28	−1.97	−2.17
Lowest recorded November stage	+2.00	+1.46	+1.00	+2.24
Average relation of the November level to—				
October level	−0.2	−0.3	−0.3	−0.2
December level	+0.2	+0.1	+0.1	+0.1

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR NOVEMBER, 1916.

W. J. HUMPHREYS, Professor in Charge of Seismological Investigations.

[Dated: Weather Bureau, Washington, D. C., Jan. 2, 1917.]

TABLE 1.—*Noninstrumental earthquake reports, November, 1916.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ALABAMA.								
	H. m.		° ′	° ′			*M. s.*			
4	12 15	Birmingham	33 32	86 50	3	1	0 2	Rumbling	Possibly due to explosion	U. S. Weather Bureau.
		CALIFORNIA.								
3	5 55	Calexico	32 40	115 28	5	1	30	None		F. R. Spencer.
3	10 05	Los Gatos	37 12	121 58	2	1	5	do		Irving H. Snyder.
	10 05	Santa Cruz	36 57	122 02	5	1	1	do		W. R. Springer.
9	9 10	Lone Pine	36 37	118 01	4	.....	.....	.....	Windows rattled	G. F. Marsh.
26	17 05	Cahuilla	33 32	116 43	5	2	5	Rumbling		Dr. W. L. Shawk.
28	7 11	Spreckels	36 35	121 38	4	3	.....	None		Spreckels Sugar Co.
		NEVADA.								
9	11 00	Sharp	38 07	115 28	2	1	Few	None		F. A. Sears.
10	9 13	Las Vegas	36 09	115 09	3	1	5	do		C. P. Squires.
	9 13	Rhyolite	36 52	116 50	4	1	.....	.....		C. E. Bulette.
10	10 15	do	36 52	116 50	4	1	45	.....		Do.
10	18 00	Pahrump	38 51	114 22	2	2	30	.....		F. A. Buol.
		NEW YORK.								
2	2 32	Caldwell	43 24	73 43	5	1	.....	Loud		Charles Forsell.
		WASHINGTON.								
21	19 30	Silverton	48 00	121 32	4	1	10	Rumbling	Shook buildings	C. M. Mackintosh.

TABLE 2.—*Instrumental reports, November, 1916.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols see REVIEW for January, 1916, p. 39.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: {E: V 10, T_0 16.7; N: V 10, T_0 15.4}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 10	.....	L_N	9 25 37	12	.....	.....	.....	Microseisms on 4, 16, 17, 20, and 24-28.
		M_N	9 26 15	10	.....	40	.....	
		C_N	9 28 00	10	.....	.....	.....	
		F_N	9 32 00	.....	.....	.....	.....	
21	.....	eL_E	6 53 30	16	.....	.....	.....	
		eL_N	6 53 38	18	.....	.....	.....	
		M_E	6 54 10	14	100	.....	.....	
		M_N	6 54 32	16	.....	90	.....	
		C_E	6 55 20	.....	.....	.....	.....	
		C_N	7 02 10	12	.....	.....	.....	
		F_E	7 04 00	.....	.....	.....	.....	
		F_N	7 11 00	.....	.....	.....	.....	

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat. 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: {E: V 10, T_0 14; N: V 10, T_0 19}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 10	.....	P_N	9 14 01	.....	.....	.....	.....	
		P_E	9 14 04	.....	.....	.....	.....	
		L_E	9 15 29	8	.....	.....	.....	
		L_N	9 15 30	7	.....	.....	.....	
		M_E	9 15 38	9	350	.....	.....	
		M_N	9 16 05	6	.....	270	.....	
		C_N	9 16 22	.....	.....	.....	.....	
		C_E	9 16 45	.....	.....	.....	.....	
		F	9 34 ..	.....	.....	.....	.....	
12	.....	eL	11 09 30	.....	.....	.....	.....	
		M	11 10 13	5	10	20	.....	
		F	11 24 00	.....	.....	.....	.....	
19	.....	eL_E	20 55 33	6	.....	.....	.....	Very faint. No phases.
		eL_N	20 55 42	5	.....	.....	.....	
		F	21 00 00	.....	.....	.....	.....	
21	.....	eP_N	6 30 41	.....	.....	.....	.....	
		eP_E	6 30 49	.....	.....	.....	.....	
		S_N	6 34 39	.....	.....	.....	.....	
		S_E	6 34 44	.....	.....	.....	.....	
		L_E	6 37 38	.....	.....	.....	.....	
		L_N	6 37 45	.....	.....	.....	.....	
		M_E	6 38 05	18	700	.....	.....	
		M_N	6 40 18	13	.....	720	.....	
		C	6 41 30	.....	.....	.....	.....	
		F	7 10 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, November, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
California. *Berkeley. University of California.*								
Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.								
(*See* Bulletin of the Seismographic Stations, University of California.								
California. *Mount Hamilton. Lick Observatory.*								
Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.								
(*See* Bulletin of the Seismographic Stations, University of California.								
California. *Point Loma. Raja Yoga Academy.* F. J. Dick.								
Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.								
Instrument: Two-component, C. D. West seismoscope.								
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 1					*400	*300		Tremors recorded during 24 hours preceding 15h on dates given; but most of these are due to firing of heavy guns at neighboring forts and on battleships.
2					*200	*200		
3					*400	*400		
4					*400	*500		
6					*400	*400		
7					*350	*300		
8					*400	*400		
10					*450	*450		
11					*500	*500		
13					*300	*200		
16					*100	*200		
18					*400	*400		
20					*300	*300		
22					*150	*150		
23					*400	*600		
24					*300	*300		
25					*200	*200		
29					*200	*200		
30					*100	*100		
*Amplitude on instrument.								
California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.								
Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters.								
(*See* Record of the Seismographic Station, University of Santa Clara.)								
Colorado. *Denver. Sacred Heart College. Earthquake Station.* A. W. Forstall, S. J.								
Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.								
Instrument: Wiechert 80 kg., astatic, horizontal pendulum.								
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 5–6								Visible activity at intervals during day.
10		P_E	9 14 00					Record can not be read on N–S owing to defect in smoking of paper.
		L_E	9 16 00					
		M_E	9 17 00	8–9	50			
		C_E	9 19 00					S_E?
		F_E	9 21 00					
21		P	6 35 00					S?; not discernible.
		L	6 42 00	10–12				Maximum rather doubtful.
		M	6 43 00	20–25	5–6	5–6		
		F_N	6 48 00					
		F_E	6 50 00					
25–26								Visible activity at intervals during day.
30		L	3 40 00					Extremely weak and uncertain.
		F	4 50 00					

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. U. S. Weather Bureau.*								
Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation 21 meters.								
Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.								
Instrumental constants.. *V* 110 *T*0 5.4								
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 10		e	9 24 30					Preliminary phases uncertain.
		L_N	9 27 54					
		M_E	9 32 00		68			
		F	9 50 00					
18		L_E	12 26 45	20				Other phases lost in microseisms. Barely perceptible on N–S.
		F	12 50 00					
21		P	6 31 59				2,690	
		S	6 36 19					
		L	6 39 41					
		F	7 40 00					
30		iP	3 22 40				2,290	Phases well defined. eS at 3h 26m 08s possibly Y, see British Association report, 1915, On Seismological Investigations.
		iS	3 26 28					
		L	3 27 30	18				
		F	4 30 00					
District of Columbia. *Washington. Georgetown University.*								
F. L. Tondorf, S. J.								
Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.								
Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.								
Instrumental constants: E *V* 165 *T*0 5.4 *ε* 0; N 143 5.2 0; *Z* *80* *3.0* *0*								
1916.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 10		e_E	9 24 19					Heavy wind markings; P and S very doubtful.
		e_N	9 24 33					
		eL_N	9 28 35					
		eL_E	9 28 43					
		M_N	9 29 40	9		8		
		M_N	9 30 37	9		6		
		M_N	9 31 18	8		4		
		M_E	9 31 54	9	8			
		M_E	9 33 45	9	4			
		F	9 50 00					
13		L?	12 26 42					Of doubtful seismicity.
		F	12 41 00					Heavy microseisms.
18		eL_E?	12 26 24					Heavy microseisms. N–S not well defined. Mainka instrument shows what appears to be e at 12h 28m 05s.
		L_E	12 29 12					
		F	12 50 00					
21		eP_E	6 31 32					Heavy microseisms. Sheet changed by mistake at 7h 32m at which time traces were still apparent; F?
		eP_N	6 31 33					
		S_E	6 36 24					
		S_N	6 36 27					
		eL_N	6 39 30					
		eL_E	6 39 36					
		L_E	6 43 21					
		L_N	6 44 18					
			VERTICAL.					
		e	*6 31 27*					
		eL	*6 39 36*					
		L	*6 45 00*	*9*				
		F	*7 16 00*					
30		e	3 22 41					Vertical shows e at 3h 22m 33s.
		S_E	3 26 29					
		S_N	3 26 31					
		eL_N	3 27 24	8				
		eL_E	3 27 26	8				
		M_N	3 33 45			4		
		M_E	3 33 59		5			
		F	4 40 00					

TABLE 2.—*Instrumental reports, November, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neuman.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instruments: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.9

(Report for November, 1916, not received.)

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants..	V	T_0	ε
E	177	3.4	4.0
N	205	3.4	3.8

(Report for November, 1916, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..	V	T_0
E	10	32
N	10	27

1916.	Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
	Nov. 10	.....	eL_E	9 28 07	.....	.....	.....	.....	
			eL_N	9 28 30	.....	.....	.....	.....	
			M_N	9 29 10	8	.....	40	.....	
			M_E	9 31 53	8	40	.....	.....	
			C	9 32 ..	.....	.....	.....	.....	
			F	9 40 ..	.....	.....	.....	.....	
	21	.....	eP_N	6 31 13	.....	.....	.....	.....	
			eS_E	6 36 16	.....	.....	.....	.....	
			eL_{EN}	6 41 20	17	.....	.....	.....	
			eL_E	6 42 31	18	.....	.....	.....	
			M_N	6 45 16	.....	.....	90	.....	
			M_E	6 45 56	.....	60	.....	.....	
			C	6 55 00	.....	.....	.....	.....	
			F	7 04 00	.....	.....	.....	.....	
	30	.....	eP_E	3 22 32	.....	.....	.....	.....	
			eP_N	3 22 48	.....	.....	.....	.....	
			S_E	3 26 22	.....	.....	.....	.....	
			S_N	3 26 27	.....	.....	.....	.....	
			eL_E	3 27 30	24	.....	.....	.....	
			eL_N	3 27 44	20	.....	.....	.....	
			M	3 22 40	.....	80	100	.....	
			C	3 35 ..	.....	.....	.....	.....	
			F	4 08 ..	.....	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ε:1
E	80	23	0
N	50	25	4:1

(Report for November, 1916, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	ε
	80	7	5:1

1916.	Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
	Nov. 10	II_F	P_N	9 15 45	.....	.....	.....	3,200	E-W not well defined.
			S_N	9 20 42	.....	.....	.....	.....	
			L_N	9 22 21	.....	.....	.....	.....	
			F	9 36 00	.....	.....	.....	.....	
	21	II_F	P_N	18 31 00	.....	.....	.....	.....	E-W not well defined.
			M_N?..	18 35 06	.....	.....	.....	.....	
			F	19 00 00	.....	.....	.....	.....	
	30	II_F	P	3 23 00	.....	.....	.....	.....	
			S?..	3 28 30	.....	.....	.....	.....	
			L	3 33 00	.....	.....	.....	.....	
			F	4 04 00	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants..	V	T_0	ε
	80	7	5:1

1916.	Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
	Nov. 10	.....	e_E	9 23 45	.....	.....	.....	.....	
			e_N	9 24 00	.....	.....	.....	.....	
			L_N	9 28 00	.....	.....	.....	.....	
			L_E	9 28 30	.....	.....	.....	.....	
			M_N	9 29 00	10	.....	19	.....	
			M_E	9 29 30	7	6	.....	.....	
			F	9 53 00	.....	.....	.....	.....	
	12	.....	e_E	13 02 15	.....	.....	.....	.....	2 sharp shocks—E-W.
			e_N	13 02 30	.....	.....	.....	.....	
			M_N	13 07 00	.....	.....	.....	.....	
			M_E	13 07 10	.....	12	.....	.....	
			F	13 09 00	.....	.....	.....	.....	
	21	.....	eP	6 32 30	.....	.....	.....	.....	
			S	6 37 30	.....	.....	.....	.....	
			L	6 45 00	.....	.....	.....	.....	
			M_E	6 47 00	25	6	.....	.....	
			M_N	6 48 00	20	.....	10	.....	
			M_N	6 51 00	.....	.....	.....	.....	
			F	7 08 00	.....	.....	.....	.....	
	30	.....	eP	3 29 20	.....	.....	.....	.....	
			S	3 33 40	.....	.....	.....	.....	
			L	3 39 00	.....	.....	.....	.....	
			M	3 41 00	.....	12	16	.....	
			F	4 08 00	.....	.....	.....	.....	

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..	V	T_0	ε
E	72	6.6	1.5:1
N	72	7.1	3.8:1

1916.	Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
	Nov 10	.....	eL_N	9 23 10	.....	.....	.....	.....	Mere trace on E-W. P and S both lost in microseisms.
			M_N	9 25 39	9.6	.....	21	.....	
			F_N	9 37 00	.....	.....	.....	.....	
	12	.....	eP_N?..	12 17 54	.....	.....	.....	.....	F lost in microseisms
			eL	12 20 48	.....	.....	.....	.....	
	21	.....	eP_N?..	6 30 49	.....	.....	.....	.....	E-W lost through defective smoking of record. All phases doubtful because of heavy microseisms.
			S_N?..	6 33 48	.....	.....	.....	.....	
			eL_N?..	6 35 50	.....	.....	.....	.....	
	30	.....	iP_N	3 18 19	.....	.....	.....	.....	
			P_E	3 18 21	.....	.....	.....	.....	
			S_E	3 21 54	.....	.....	.....	.....	
			iS_N	3 22 10	.....	.....	.....	.....	
			L_E	3 23 30	.....	.....	.....	.....	
			L_N	3 23 37	.....	.....	.....	.....	
			M_N	3 30 51	13	.....	16	.....	
			F_E	4 00 00	.....	.....	.....	.....	
			F_N	4 03 00	.....	.....	.....	.....	

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ε
E	13	22	4:1
N	14	25	4:1

1916.	Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
	Nov 10	.....	e_N	9 28 34	6	.....	.....	.....	
			e_E	9 29 35	7	.....	.....	.....	
			M_N	9 30 16	13	.....	71	.....	
			F_E	9 45 00	.....	.....	.....	.....	
			F_N	9 48 00	.....	.....	.....	.....	
	21	.....	e_N	6 34 12	9	.....	.....	.....	Phases not differentiated.
			e_E	6 36 14	5	.....	.....	.....	
			M_N	6 51 02	12	.....	36	.....	
			F_E	7 17 00	.....	.....	.....	.....	
			F_N	7 19 00	.....	.....	.....	.....	
	24	.....	e_N	12 34 41	33	.....	.....	.....	Obscured by irregular microseisms.
			F_N	13 21 00	.....	.....	.....	.....	
	30	.....	P_N	3 23 52	6	.....	.....	.....	
			P_E	3 24 01	3	.....	.....	.....	
			S_N	3 28 05	11	.....	86	.....	
			S_E	3 28 11	5–10	.....	.....	.....	
			L_E	3 30 09	22	.....	.....	.....	
			L_N	3 30 31	20	.....	.....	.....	
			F_E	4 20 00	.....	.....	.....	.....	
			F_N	4 21 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, November, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.								
Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.								
Instruments: Two Bosch-Omori 100 kg.								
Instrumental constants..			V 10	T_0 20				
1916. Nov. 20	.....	P	*H. m. s.* 18 16 02	*Sec.*	μ	μ	*Km.* 315	Direction?
		L	18 16 40	.....	.....	.....	.....	
		M_N	18 16 48	.....	.....	50	.....	
		M_E	18 16 50	.....	40	.....	.....	
		F_E	18 20 00	.....	.....	.....	.....	
		F_N	18 21 00	.....	.....	.....	.....	
21	.....	P_N	6 29 18	.....	.....	.....	2,010	Movement barely perceptible on E-W.
		S_N	6 33 00	.....	.....	.....	.....	
		L_N	6 35 18	.....	.....	.....	.....	
		M_N	6 38 34	.....	.....	100	.....	
		F	7 04 00	.....	.....	.....	.....	
Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.								
Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.								
Instruments: Two Bosch-Omori.								
Instrumental constants..			V E. 10 N. 10	T_0 18 19.5				
1916. Nov. 12	.....	L	*H. m. s.* 13 10 03	*Sec.* 2	μ	μ	*Km.*	The shock was distinctly felt in Vieques. Doors rattled, and there was a faint rumbling.
		M	13 10 08	2	550	400	.....	
		C	13 11 00	2	.....	.....	.....	
		F	13 14 00	.....	.....	.....	.....	
25	.....	P	13 14 38	.....	.....	.....	.....	
		L	13 14 51	2	.....	.....	.....	
		M	13 15 08	2	30	40	.....	
		F_N	13 18 ..	.....	.....	.....	.....	
		F_E	13 20 ..	.....	.....	.....	.....	
25	.....	P	13 46 30	.....	.....	.....	.....	Slight shocks, resembling microseismic tremors, occurred during the 48 hours following this quake.
		L	13 46 44	3	.....	.....	.....	
		M_E	13 46 57	4	40	.....	.....	
		M_N	13 47 02	2	.....	40	.....	
		F	13 50 00	.....	.....	.....	.....	
30	.....	P_E	3 18 46	3	.....	.....	.....	Phases and periods not well defined.
		L_E	3 19 03	6	.....	.....	.....	
		L_N	3 19 03	8	.....	.....	.....	
		M_N	3 20 15	18	.....	900	.....	
		M_E	3 20 52	14	300	.....	.....	
		C_N	3 25 00	12	.....	.....	.....	
		C_E	3 26 00	8	.....	.....	.....	
		F_N	3 37 00	.....	.....	.....	.....	
		F_E	3 46 00	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.								
Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.								
Instruments: Two Bosch-Omori, mechanical registration.								
Instrumental constants..			V E 10 N 10	T_0 15 16				
1916. Nov. 10	.....	e_N	*H. m. s.* 9 24 17	*Sec.*	μ	μ	*Km.*	Phases indeterminate.
		e_E	9 29 54	.....	.....	.....	.....	
		M_N	9 30 42	.....	.....	200	.....	
		F	10 00 00	.....	.....	.....	.....	
21	.....	S	6 37 42	.....	.....	.....	.....	P uncertain.
		L	6 40 40	.....	.....	.....	.....	
		F	7 30 00	.....	.....	.....	.....	
24	.....	L_N	12 36 40	.....	.....	.....	.....	Record faint, not discernible on E-W.
		F_N	12 50 00	.....	.....	.....	.....	
30	.....	P	3 23 21	.....	.....	.....	.....	
		S	3 26 46	.....	.....	.....	.....	
		L	3 27 49	.....	.....	.....	.....	
		F	4 11 00	.....	.....	.....	.....	
Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.								
Lat., 45° 23′ 38″ N., long., 75° 42′ 57″ W. Elevation, 83 meters.								
Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.								
Instrumental constants:			V 120	T_0 26				
1916. Nov. 10	.....	e?	*H. m. s.* 9 19 00	*Sec.*	μ	μ	*Km.*	Microseisms mask first phases.
		e?	9 24 07	.....	.....	.....	.....	
		e?	9 24 40	.....	.....	.....	.....	
		eL	9 27 48	.....	.....	.....	.....	
		M	9 29 30	14	8	70	.....	
		L	9 32 00	6	.....	.....	.....	
		F	10 00 00	.....	.....	.....	.....	
18	.....	eL_E	12 31 36	20	.....	.....	.....	Microseisms completely mask N-S component.
		F	12 45 00	.....	.....	.....	.....	
21	.....	*O*	*6 25 39*	.....	.....	.....	3,580	
		P	6 32 26	1- 2	.....	.....	.....	
		S	6 37 48	.....	.....	.....	.....	
		eL	6 40 24	12-14	.....	.....	.....	
		L_E	6 45 00	20	.....	.....	.....	
		L_N	6 49 00	18	.....	.....	.....	
		L_E	6 53 00	16	.....	.....	.....	
		L_E	7 01 00	12	.....	.....	.....	
		F	7 25 00	.....	.....	.....	.....	
24	.....	eL_N	12 36 18	36	.....	.....	.....	Microseisms mask other phases.
		L_E	12 42 00	28	.....	.....	.....	
		F	13 — —	.....	.....	.....	.....	
30	.....	*O*	*5 17 56*	.....	.....	.....	2,870	
		$1P_N$	3 23 40	.....	.....	.....	.....	
		S	3 28 14	.....	.....	.....	.....	
		eL	3 30 18	20	.....	.....	.....	
		L	3 34 00	18-17	.....	.....	.....	
		L	3 37 00	12-11	.....	.....	.....	
		L	3 45 00	15	.....	.....	.....	
		L	3 53 00	14	.....	.....	.....	
		L	4 02 00	12-11	.....	.....	.....	
		L	4 06 00	13	.....	.....	.....	
		L	4 10 00	11	.....	.....	.....	
		F	4 45 00	.....	.....	.....	.....	

O—time at origin.

TABLE 2.—*Instrumental reports, November, 1916*—Continued.

Canada. *Toronto. Dominion Meteorogical Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.50″.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Nov. 3	.....	e.....	22 31 48	.....	.....	.....	.....	Gradual thickening.
		L.....	22 40 48	.....	*200	.....	.....	
		F.....	22 52 06	.....	.....	.....	.....	
10	.....	iL.....	9 29 06	.....	.....	.....	.....	P and S not recorded.
		M.....	9 29 30	.....	*300	.....	.....	
		F.....	9 39 00	.....	.....	.....	.....	
11	.....	L.....	14 18 06	.....	.....	.....	.....	Gradual thickening at principal portions. P and S not recorded.
		eL.....	14 20 00	.....	.....	.....	.....	
		M.....	14 23 30	.....	*400	.....	.....	
		F?.....	14 51 42	.....	.....	.....	.....	
11	.....	L.....	16 03 00	.....	.....	.....	.....	P and S lost in changing paper.
		eL.....	16 08 06	.....	.....	.....	.....	
		M.....	16 11 30	.....	*300	.....	.....	
		F?.....	16 56 48	.....	.....	.....	.....	
11	.....	L.....	17 26 06	.....	*50	.....	.....	Very doubtful as to being seismic. Thickening at intervals.
		F?.....	17 45 12	.....	.....	.....	.....	
13	.....	L.....	12 40 48	.....	.....	.....	.....	P and S not recorded.
		eL.....	12 44 18	.....	.....	.....	.....	
		eL.....	12 49 48	.....	.....	.....	.....	
		M.....	12 52 36	.....	*300	.....	.....	
		F.....	13 36 12	.....	.....	.....	.....	
14	.....	L?.....	23 15 06	.....	*50	.....	.....	Doubtful as to being seismic.
18	.....	L?.....	12 28 54	.....	.....	.....	.....	Slight thickening.
		L?.....	12 54 24	.....	.....	.....	.....	Phases masked by air currents.
21	.....	e.....	6 35 42	.....	.....	.....	.....	Real P waves may not have been recorded. Possibly off the coast of Mexico.
		P–iS..	6 36 30	.....	.....	.....	.....	
		iS.....	6 38 48	.....	.....	.....	.....	
		iL.....	6 44 06	.....	.....	.....	.....	
		M.....	6 45 42	.....	*2,800	.....	.....	
		eL.....	6 47 48	.....	.....	.....	.....	
		M.....	6 50 12	.....	*2,300	.....	.....	
		L.....	6 51 54	.....	.....	.....	.....	
		L.....	6 59 00	.....	.....	.....	.....	
		Repeat	7 53 18	.....	.....	.....	.....	
		F.....	8 08 00	.....	.....	.....	.....	
24	.....	eL?...	0 13 06	.....	.....	.....	.....	Air currents going on. F in air currents.
		eL?...	0 17 24	.....	.....	.....	.....	
24	.....	L.....	12 43 18	.....	.....	.....	.....	Thickenings. P and S not recorded. F in air currents.
		L.....	12 46 12	.....	.....	.....	.....	
		eL.....	12 48 36	.....	.....	.....	.....	
		M.....	12 51 30	.....	*200	.....	.....	
30	.....	P?.....	3 24 12	.....	.....	.....	2,590	A marked quake. P not well defined. Possibly in West Indies.
		iS.....	3 28 24	.....	.....	.....	.....	
		iL.....	3 31 00	24	.....	.....	.....	
		L.....	3 33 30	24	.....	.....	.....	
		M.....	3 35 24	.....	*2,400	.....	.....	
		eL.....	3 52 06	.....	.....	.....	.....	
		eL.....	3 53 36	.....	.....	.....	.....	
		eL.....	3 55 24	.....	.....	.....	.....	
		eL.....	3 57 06	.....	.....	.....	.....	
		F.....	4 50 48	.....	.....	.....	.....	

*Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm., swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Nov. 3	.....	L?.....	22 23 36	.....	.....	.....	.....	
10	.....	P.....	9 17 46	.....	.....	.....	260?	Probably in eastern Washington.
		L.....	9 18 15	.....	.....	.....	.....	
		M.....	9 19 05	.....	*2000	.....	.....	
		F.....	9 31 08	.....	.....	.....	.....	
11	.....	S.....	14 01 00	.....	.....	.....	.....	
		L.....	14 04 00	.....	.....	.....	.....	
		M.....	14 07 30	.....	*300	.....	.....	
		F.....	14 46 30	.....	.....	.....	.....	
11	.....	S.....	15 47 30	.....	.....	.....	.....	
		L.....	15 51 30	.....	.....	.....	.....	
		M.....	15 55 30	.....	*300	.....	.....	
		F.....	16 15 30	.....	.....	.....	.....	
13	.....	L.....	12 31 20	.....	.....	.....	.....	P?
		M.....	12 38 17	.....	*100	.....	.....	
		F.....	12 52 10	.....	.....	.....	.....	
14	.....	L.....	23 25 03	.....	*50	.....	.....	
18	.....	P?.....	11 57 05	.....	.....	.....	.....	
		L.....	12 09 58	.....	.....	.....	.....	
		M.....	12 14 56	.....	*200	.....	.....	
18	.....	L.....	12 39 14	.....	*200	.....	.....	May be part of preceding quake.
20	.....	L.....	21 47 19	.....	.....	.....	.....	
		M.....	21 53 16	.....	*100	.....	.....	
20	.....	P?.....	22 58 43	.....	.....	.....	.....	
		L.....	22 59 43	.....	.....	.....	.....	
		M.....	23 01 42	.....	*200	.....	.....	
		F.....	23 05 40	.....	.....	.....	.....	
21	.....	P.....	6 39 26	.....	.....	.....	2,050	
		S.....	6 42 54	.....	.....	.....	.....	
		L.....	6 47 22	.....	.....	.....	.....	
		M.....	6 52 19	.....	*4500	.....	.....	
		F.....	7 55 18	.....	.....	.....	.....	
			VERTICAL.					
					A_Z			
		S.....	*6 43 12*	*6*	.....	.....	.....	P?
		L.....	*6 47 00*	*18–20*	.....	.....	.....	
		M.....	*6 50 18*	.....	*17*	.....	.....	True earth movement.
		F?....	*7 09 00*	.....	.....	.....	.....	
24	.....	P?.....	0 09 17	.....	.....	.....	.....	
		L.....	0 14 17	.....	.....	.....	.....	
		M.....	0 18 47	.....	*200	.....	.....	
		F.....	0 27 47	.....	.....	.....	.....	
24	.....	L?.....	13 03 53	.....	.....	.....	.....	P?
		M.....	13 06 51	.....	*400	.....	.....	
		F?.....	13 14 47	.....	.....	.....	.....	
25	.....	P?.....	21 06 34	.....	.....	.....	.....	May not be seismic. L?
		M.....	21 09 18	.....	*100	.....	.....	
		F.....	21 11 11	.....	.....	.....	.....	
27	.....	P?.....	7 17 32	.....	.....	.....	.....	
		L.....	7 21 00	.....	.....	.....	.....	
		M.....	7 24 28	.....	*200	.....	.....	
		F.....	7 30 55	.....	.....	.....	.....	
30	.....	P.....	3 34 00	.....	.....	.....	6,000	Beginning of P not defined. Trace thick. Distance, from S–L.
		iS.....	3 39 00	.....	.....	.....	.....	
		L.....	3 48 12	.....	.....	.....	.....	
		eL.....	3 49 54	.....	.....	.....	.....	
		M.....	3 51 36	.....	*1000	.....	.....	
		eL.....	4 02 00	.....	.....	.....	.....	
		F.....	4 24 04	.....	.....	.....	.....	

*Trace amplitude.

TABLE 3.—*Late seismological reports.* (*Instrumental.*)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
New York. *Buffalo. Canisius College.* John A. Curtin, S. J.								
Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.								
Instrument: Wiechert 80 kg. horizontal.								
Instrumental constants..				V 80	T_0 7	ε 5:1		
1916. Sept. 21	.....	.....	*H. m. s.*	*Sec.*	μ	μ	*Km.*	Microseisms during day and night.
23	.....	eP_N...	5 49 00	.....	.....	.....	.....	E-W indistinct.
		S_N....	5 55 00	.....	.....	.....	.....	
		M_N....	6 01 00	.....	.....	.....	.....	
		F_N....	6 06 00	.....	.....	.....	.....	
28	.....	i_E.....	15 58 00	.....	.....	.....	.....	Heavy microseisms. Very short period.
		i_N.....	15 58 10	.....	.....	.....	.....	
		F.....	16 00 40	.....	.....	.....	.....	
Oct. 3	.....	eP.....	1 36 00	.....	.....	.....	.....	
		S_E.....	1 44 00	.....	.....	.....	.....	
		S_N.....	1 44 15	.....	.....	.....	.....	
		L_E.....	1 57 00	.....	.....	.....	.....	
		L_N.....	1 57 20	.....	.....	.....	.....	
		F.....	2 15 00	.....	.....	.....	.....	
3	.....	S_N....	5 03 30	.....	.....	.....	.....	
		M_N....	5 06 00	.....	.....	.....	.....	
		F_N....	5 10 00	.....	.....	.....	.....	
22	.....	.....	16 14 00	.....	.....	.....	.....	Severe microseisms.
			16 15 00	.....	.....	.....	.....	

SEISMOLOGICAL DISPATCHES.[1]

Glenns Falls, N. Y., Nov. 1, 1916.

An earthquake shock which lasted several seconds was felt in sections of northern New York to-night. At this place, which apparently was the center of the disturbance, houses were shaken so severely that dishes were thrown from shelves and pictures from walls. No serious damage reported. (Assoc. Press.)

San Salvador, Republic of Salvador, Nov. 2, 1916.

Reports received here from Nicaragua say the volcano Santiago there is throwing out lava and ashes. (Assoc. Press.)

Redding, Cal., Nov. 2, 1916.

Lassen Peak began belching mighty balls of black smoke to-day at intervals of from 5 to 10 minutes. The most violent eruption of the year took place yesterday afternoon according to observers reaching here to-day. (Assoc. Press.)

Birmingham, Ala., Nov. 4, 1916.

A distinct earthquake tremor was felt here at 6:15 o'clock this morning, the local Weather Bureau announced. Windows were rattled and china knocked from the cupboards of several homes. (Assoc. Press.)

Birmingham, Ala., Nov. 4, 1916.

The explosion which occurred about 3 o'clock this morning caused an earth shock which was distinctly felt in Birmingham, and persons in this city at first believed the tremor to be an earthquake. It lasted but a few seconds. (Assoc. Press.)

Tokyo, Japan, Nov. 29, 1916.

Considerable damage has been caused by an earthquake in middle Japan. Many houses have been destroyed in Kobe, Osaka, and Kyoto. The railway station at Kyoto was damaged, and several pedestrians were hurt by falling walls and roofs in that town and in Kobe. (Assoc. Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

SECTION VI.—BIBLIOGRAPHY.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

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SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

P. C. DAY, Climatologist and Chief of Division.

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

For November as a whole the barometric pressure averaged above the normal throughout the United States, but in the central and extreme eastern Canadian Provinces it was somewhat below the average. The monthly means in the lower Missouri and central and northern Mississippi Valleys and to the northeastward averaged near the normal, and elsewhere the departures were not large, except that in the far Northwest the plus values were quite marked.

The month opened with relatively high pressure throughout practically all sections, except the New England States, New York, the northern portion of the Lake region, and the Florida Peninsula, where it was below the average. During the next few days low pressure obtained generally in the northern part of the country, but high readings continued throughout the South. The remainder of the first half of the month was marked by the successive passage across the country of several rather extensive and well-defined low and high pressure areas, while high pressure prevailed generally in the southeastern States. During the second half of the month the pressure continued relatively high for much of the time, except that in the early part of the third decade a rather extensive low pressure area moved from the far Southwest northeasterly to the Lake region and thence eastward, and an occasional low area crossed the northern border States and Canada.

The month closed with generally high pressure, except in the Atlantic coast States, the Lake region, the far Northwest, and practically all of Canada save the eastern Provinces, where it was below the average.

The distribution of the highs and lows was generally favorable for southerly winds in the Great Central Valleys, the lower Lake region and northeastern States, and northeasterly in the South Atlantic States, while in much of the Lake region, the upper Mississippi Valley, and the Central and Northern Plains region northerly and westerly winds were frequent during the month. Elsewhere variable winds prevailed.

TEMPERATURE.

At the beginning of November seasonable temperatures prevailed in most portions of the country, but by the 3d high temperatures for November overspread the Rocky Mountain and Plains States, and during the next few days there was a warming up in the Mississippi Valley. On the 6th cool weather appeared to the westward of the Rocky Mountains and in Montana, and on the 8th and 9th there was a decided fall of temperature in the west Gulf States and the Mississippi Valley. About the 10th, a marked cold wave set in over the far Northwest, but its progress eastward was comparatively slow. The temperature for the first 12 days of November averaged slightly above the normal from the Rocky Mountain region westward and in the Upper Missouri Valley; but it was decidedly above the average in most of the eastern districts, specially in the middle Mississippi and the Ohio Valleys, the Lake region, and the southern Appalachian mountain district. On the 13th and 14th, with the advance of the cold wave above referred to, temperatures fell to readings unusually low for November in Wyoming, Montana, and most sections west of the Rockies. The cold wave reached the Atlantic coast about the 15th, and decidedly cold weather for the season occurred in the south Atlantic and east Gulf States. In the Gulf States w of Florida freezing temperatures were experienc points, save along the immediate coast. At the sa time temperatures had somewhat moderated in northern Plains region, and by the 19th they were se le generally over the country. The six-day riod November 13 to 18 averaged much colder than normal in almost all portions of the country, except the middle and upper Missouri Valley where the latter half of the period was quite warm. From the 21st to 23d, unseasonably high temperatures occurred from the Rio Grande Valley northeastward to Lake Michigan, but at the same time rather low readings obtained in the Rocky Mountain districts and the central and southern Plains States, which a little later was also the case in the Mississippi Valley, and they were below the seasonable average in eastern districts. The latter part of the month was rked by generally mild temperatures in most parts of untry. During the final 12 days in the region west of Rocky Mountains the weather averaged slightly cooler than normal, and east of the Rockies warmer than the avearge, especially in northern districts.

The month as a whole averaged slightly warmer than normal in most districts east of the Rocky Mountains, save in Texas, but in the central valleys, Minnesota, and the Dakotas, the excess was rather marked. In the Rocky Mountain and Plateau States the month averaged cooler than normal, especially in Idaho, Nevada, Utah, Wyoming, and the Pacific States. At some time during the month freezing temperatures occurred in practically all sections of the country except the Florida Peninsula and along the immediate coast of Louisiana and Texas, and the middle and southern California coast.

PRECIPITATION.

Fair weather prevailed during the first few days of November in most portions of the country. About the 6th unsettled weather developed in the southern Plains region and overspread most sections to the northward and rather heavy rainfall occurred on the 8th and 9th at several stations from Kansas northeastward to Lake Michigan. About the 15th heavy rains occurred at many points in Florida, and from the 21st to 23d a storm moved from the Rio Grande Valley northeastward to the Great Lakes, causing widespread and generally heavy rains to the eastward and southeastward of its path.

During the closing days of the month overcast weather predominated in many eastern districts, with some generous rains in the Atlantic coast States from North Carolina to Maine, but fair weather, as a rule, prevailed west of the Mississippi.

The precipitation for the month, as a whole, was fairly plentiful over most of the Florida Peninsula, New England, and eastern New York, the southern Appalachian district and over a strip extending from central Texas northward and northeastward to the upper Lake region. It was moderate for the season in northern Idaho, the western portions of Washington and Oregon, but was considerably below the normal in most of California. Over large portions of the country the rainfall was light, especially so in the middle Gulf region, southern Georgia, the interior of the Carolinas, the upper Mississippi Valley, and most of the Plains region. In Arizona and southeastern California there was practically no rain, and it was scanty in New Mexico, most of Utah and Nevada, and in southern Idaho.

RELATIVE HUMIDITY.

The month, as a whole, was generally drier than the average over the greater portion of the country, except in relatively small areas in the central portions of the Rocky Mountain and Plains States, and parts of the Lake region, New England, and the Middle and South Atlantic States, where the relative humidity was near or somewhat above the normal. However, at many stations scattered irregularly throughout the country, the mornings were damper and the evenings drier than the respective averages.

GENERAL SUMMARY.

The weather of November, 1916, was favorable in all sections of the country for outdoor work, except that in the Southern States and eastern Oregon dry weather prevailed for plowing and seeding, while in California the cold weather hindered farm operations.

Winter wheat was reported in good condition in most northern sections, but growth was delayed throughout much of the southern part of the country by lack of moisture. However, the rains during the latter part of the month were beneficial in the Southern States, and planting, previously delayed by dry weather, made good progress. The growth of most winter grain was retarded somewhat in the lower Mississippi Valley by the freeze of the middle of the month.

Except in South Carolina, cotton was practically all harvested, conditions for this work being favorable during most of the month. Cold weather damaged potatoes in Mississippi, Louisiana, Colorado, Washington, and Oregon, and apples in Colorado, Washington, and Oregon. It also severely injured truck in practically all Southern States, and sugar cane in the same region to some extent.

The weather was favorable for ripening citrus fruit in Arizona, but frost during the second decade of the month caused serious damage to the olives in California, and in some parts of the State to citrus fruit. Satsuma oranges were uninjured in Alabama, but were damaged in Mississippi by the cold wave of the middle of the month, and about 20 per cent of the citrus fruit in Texas was injured.

74923—17——4

Average accumulated departures for November, 1916.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0–10		Per ct.	
New England	39.1	−0.2	− 4.5	2.44	−1.0	− 4.80	5.6	−0.2	74	− 4
Middle Atlantic	45.9	+1.3	+ 7.6	1.74	−1.1	− 5.80	4.8	−0.5	70	− 5
South Atlantic	55.9	+1.8	+11.0	1.36	−1.6	−11.80	3.5	−1.0	74	− 4
Florida Peninsula	71.0	+0.4	− 1.4	2.73	+0.5	−12.60	4.6	+0.1	75	− 5
East Gulf	56.9	+1.3	+ 8.9	2.15	−1.4	− 2.60	3.1	−1.5	69	− 7
West Gulf	56.9	+0.5	+13.2	2.15	−1.0	− 6.80	3.2	−1.4	68	− 6
Ohio Valley and Tennessee	47.1	+2.5	+ 4.2	1.64	−1.8	− 2.40	3.7	−2.0	68	− 5
Lower Lakes	39.9	+0.8	+ 0.9	1.84	−1.2	− 3.30	6.2	−1.1	74	− 3
Upper Lakes	35.7	+1.7	+ 2.5	1.81	−0.6	+ 1.90	6.9	−0.2	78	− 2
North Dakota	29.2	+4.6	−13.0	0.18	−0.6	− 0.50	4.8	−0.6	75	− 4
Upper Mississippi Valley	40.9	+3.2	+ 6.2	1.60	−0.4	− 1.60	4.8	−0.5	72	− 2
Missouri Valley	40.9	+3.5	+10.9	1.38	+0.1	− 5.80	3.8	−1.0	68	− 3
Northern slope	30.4	−1.6	−15.0	0.59	−0.2	+ 0.20	4.6	−0.2	66	− 1
Middle slope	42.8	+1.1	+ 5.1	1.16	+0.2	− 3.90	3.0	−0.9	65	+ 3
Southern slope	49.7	−1.3	+14.1	0.48	−0.7	− 4.70	2.6	−2.6	59	− 8
Southern Plateau	47.2	−1.8	− 5.2	0.12	−0.5	+ 1.00	1.6	−1.2	43	0
Middle Plateau	35.2	−4.3	−10.1	0.32	−0.6	+ 0.60	2.9	−1.0	54	− 4
Northern Plateau	34.3	−4.4	−20.9	1.29	−0.1	+ 0.70	5.8	0.0	66	− 8
North Pacific	43.4	−2.1	− 9.8	5.90	−1.4	− 9.70	6.1	−1.4	80	− 4
Middle Pacific	50.2	−2.8	− 5.8	1.46	−1.7	− 1.80	3.6	−0.9	63	−12
South Pacific	55.4	−1.6	− 6.2	0.20	−1.1	+ 4.80	2.5	−0.8	64	− 3

WEATHER CONDITIONS ON THE NORTH ATLANTIC OCEAN DURING NOVEMBER, 1915.

The data presented are for November, 1915, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLIV–142) shows for November, 1915, the averages of pressure, temperature, and the prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon), together with the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of the average pressure for the month, as shown on Chart IX, presents some unusual features. There was only a trace of the usual North Atlantic or Azores HIGH, although a small area of high pressure, with a crest of 30.05 inches, existed near the position normally occupied by this center of action, with its normal crest of 30.15 inches. The continental HIGH, with a crest of 30.15 inches, was slightly south of its usual position, the isobar of 30.1 inches passing between the south coast of Florida and Cuba and extending as far east as the 69th meridian. There was a well-developed LOW, with average minimum pressure of 29.75 inches, near latitude 55° N., longitude 46° W., but it was considerably south and west of the usual position of the Icelandic LOW. There were indications of a second LOW in the vicinity of the Scandinavian Peninsula, although the center was apparently outside the limits of the chart.

The mean monthly pressure gradient between the higher and lower latitudes was somewhat less than usual, although in many localities the changes in barometric readings from day to day were abnormal. In the 5-degree square between latitudes 30°–35° and longitudes 25°–30° the lowest barometer reading during the month

was 29.67 inches on the 25th, and the highest 30.33 inches on the 9th.

Dividing the month into three decades, the average reading in this square for the first was 30.17 inches; for the second, 30.11 inches; and for the third, 29.86 inches, while the mean for the month was 30.05 inches, and the normal is 30.15 inches. In the 5-degree square near the coast of Ireland, or between latitudes 50°–55° N. and longitudes 10°–15° W., the lowest barometric reading was 28.89 inches on the 30th, and the highest 30.53 inches the 25th. The average pressure for the first decade was 29.27 inches; for the second, 29.86 inches; and the third, 30.03 inches, the monthly mean being 29.95 inches, and the normal 29.88 inches. In the region southeast of Greenland, between latitudes 55°–60°, longitudes 35°–40°, the lowest reading was 29.10 inches on the 27th, and the highest 30.44 inches on the 24th. The average for the first decade was 29.86 inches; the second, 29.45 inches; and the third, 29.98 inches; the monthly mean was 29.76 inches, and the normal is 29.68 inches. In the waters between the African coast and the Canary Islands the lowest reading was 29.60 inches on the 28th, and the highest 30.24 inches on the 15th. The average for the first decade was 29.95 inches; the second, 30.14 inches; and the third, 29.87 inches; the monthly mean was 29.99 inches, and the normal is 30.02 inches.

These figures are given to show the great irregularity in the distribution of pressure during the month and the differences that existed over separate parts of the ocean.

It may be noted that in the first 5-degree square mentioned the highest pressure occurred in the first decade of the month and the lowest in the last, while in the square adjacent to the west coast of Ireland the highest prevailed during the last 10 days and the lowest in the middle period of the month.

In the Caribbean Sea and Gulf of Mexico the pressure was comparatively uniform during the month, and the departures from the normal were also small.

GALES.

In the waters adjacent to the European coast the number of gales reported during the month was somewhat above the normal and the same conditions existed over the greater part of the ocean, although there were some exceptions. They were unusually numerous in the region between the 40th meridian and the American coast and the 35th and 50th parallels. The greatest number during the month occurred in the 5-degree square between latitudes 35°–40° N. and longitudes 65°–70° W., where they were reported on 11 days, a percentage of 37, while the normal for that square is 12 per cent. There were other localities where the positive departure was nearly as large, the month as a whole being unusual for its stormy character.

From November 1 to 3 two extensive areas of low pressure existed; one central near the Canadian coast and the other covering a large part of England and France. They were both, however, of comparatively light intensity and no specially heavy winds were reported from the vicinity of their centers. By the morning of the 4th the first LOW had moved about 5 degrees in a southerly direction, moderate winds prevailing. The second was central in Spain and several vessels in the vicinity of the Madeiras encountered gales of from 40 to 50 miles per hour; hail also was reported. On November 6 there was a well-developed LOW central about 12 degrees east of New York, and heavy northerly winds prevailed between its center and the American coast. On the 7th the conditions were about the same, while by the 8th the center was near latitude 40°, longitude 55°; the intensity of the wind remained about the same and fog was encountered in the northern quadrants of the storm area. On November 9 a well-defined LOW appeared central on the west coast of Scotland; the lowest barometric reading was 28.82 inches, while gales of over 50 miles an hour, accompanied by hail, were reported. This disturbance moved in a northeasterly direction, and on the 10th covered a large portion of the North Sea and a part of the Scandinavian Peninsula, but with little change of pressure. One vessel off the north coast of Scotland reported a gale of 75 miles an hour. On November 11 a LOW (I on Chart IX) was central near latitude 53°, longitude 23°; but while the barometer read as low as 28.71 inches there were no specially heavy winds reported in its vicinity. This storm moved in an easterly direction, reaching, on the 12th, a point about 100 miles south of the southern coast of Ireland. The barometer had fallen to 28.37 inches, and in the storm area, which extended as far west as the 22d meridian and between the 45th and 52d parallels, gales of from 40 to 75 miles per hour prevailed, one vessel reporting hail. This disturbance then moved southeastward, and on the 13th had reached the vicinity of Denmark; but the barometer had risen to 28.82 inches and the velocity of the wind diminished somewhat, although gales of from 40 to 50 miles per hour, accompanied by snow and hail, were still reported. On the 14th a LOW (II on Chart IX) of light intensity was central near Brownsville, Tex.; thence it moved rapidly in a northeasterly direction to the vicinity of near New York on the morning of the 15th; the barometer had fallen to 29.36 inches, but there were no winds of gale force recorded. This LOW continued on its northeasterly course and on the 16th was near Newfoundland. While the winds near the center of the storm were of moderate velocity, there was a large area between that point and the Bermudas, where gales of from 40 to 60 miles prevailed. This disturbance remained nearly stationary during the next 24 hours, on the 17th the center being only slightly north of its position on the previous day and the conditions of wind and weather had changed but little. It then moved rapidly due eastward and on the 18th the approximate center was at latitude 53° N., longitude 40° W., although it is impossible to locate its position accurately, as no reports were received for this day from points north of latitude 51° and west of 30° W. Unusually stormy conditions continued over a large territory west of the 40th meridian and north of the 35th parallel, while snow and hail were reported from a number of vessels. The storm continued eastward but with a lessened rate of translation, and on the 19th its center was near latitude 51° N., longitude 34° W. The minimum barometer reading still remained below 29 inches, and while the storm area was much less extensive than on the day before a number of vessels between 40°–46° N. and 40°–48° W. reported northwesterly gales of from 40 to 75 miles, accompanied by hail and snow. Traces of this LOW could be seen on the 20th, but it had increased in area and was rapidly filling in, although gales of diminished force were still encountered in the southeast quadrant.

On November 21 and 22, 1915, a LOW of moderate intensity covered a large part of eastern Canada and the Gulf of St. Lawrence. On the 23d the center of this disturbance was about 4 degrees east of Saint Johns, N. F., with moderate winds, and fog prevailing for the most part, and hail was reported from one vessel.

On November 24 a LOW (III on Chart IX) was central near latitude 37°, longitude 66°; the lowest barometric reading was 29.78 inches, and moderate gales were re-

ported from a small area near the center. By the 25th this disturbance had moved in an easterly direction to a point near latitude 38°, longitude 58°; the barometer had fallen to 29.56 inches, and heavy gales prevailed over a large territory between 30°—45° N. and 55°—70° W. There was a slight northeastward movement of this disturbance during the next 24 hours, and on the 26th it was central near latitude 40°, longitude 58°. North of the center the winds were moderate and the weather foggy, while west of that point gales of from 40 to 50 miles an hour prevailed to the 70th meridian. This LOW then curved sharply toward the south, having increased in extent and decreased in intensity, and on the 27th the center was near latitude 37°, longitude 57°, with winds of moderate force. The disturbance then moved northward, and on the 28th was central near latitude 40°, longitude 55°, with little change in pressure and conditions of wind and weather. Its rapid eastward movement brought its center, on the 29th, near latitude 42°, longitude 47°, where the conditions were nearly the same as on the previous day.

On November 27 a LOW (IV on Chart IX) apparently existed in the vicinity of southern Iceland, although it is impossible to determine its position accurately on account of lack of observations. This LOW moved rapidly in a due southerly direction, and on the 28th was central near latitude 56°, longitude 22°; the lowest barometer reading was 28.97 inches, and strong westerly and northwesterly gales, accompanied by hail, were reported from the southwest quadrant. The disturbance then moved slowly toward the east, and on the 29th was apparently central near latitude 55°, longitude 17°; the intensity remained about the same as on the day before, and there was little change in wind and weather, as strong gales still prevailed over the steamer lanes between the 20th and 32d meridians. The depression continued its slow easterly movement, and on the 30th the center was near latitude 55°, longitude 16°, while westerly and northwesterly gales of from 40 to 70 miles an hour continued to rage in the southern and southwestern quadrants. It then changed its course slightly toward the south, and on December 1 was central in southern Ireland; the barometer had risen somewhat since the day before and the force of the wind diminished, although moderate gales of from 40 to 50 miles were reported from a limited area off the French coast.

TEMPERATURE.

The temperature of the air over the ocean was, as a rule, considerably above the normal. In the waters adjacent to the European coast the departures ranged from 0 to +2 degrees, while along the northern steamer routes there was a gradual increase of temperature from the East toward the West, and positive departures of from +10 to +12 degrees existed in some of the 5-degree squares north of the 45th parallel and west of the 45th meridian. South of the 45th parallel the departures were comparatively uniform, ranging from 0 to +3 degrees, except in the Gulf of Mexico, where the positive departures were considerably larger than at the adjacent land stations.

The temperature departures at a number of Canadian and U. S. Weather Bureau stations on the Atlantic and Gulf coasts were as follows:

	°F.		°F.
St. Johns, Newfoundland	+3.9	Norfolk, Va.	+1.2
Sydney, C. B. I.	+4.3	Hatteras, N. C.	+0.6
Halifax, N. S.	+5.0	Charleston, S. C.	+3.3
Eastport, Me.	+1.7	Key West, Fla.	+1.2
Portland, Me.	+3.2	Tampa, Fla.	+3.9
Boston, Mass.	+4.2	Pensacola, Fla.	+3.5
Nantucket, Mass.	+0.6	New Orleans, La.	+5.6
Block Island, R. I.	+0.5	Galveston, Tex.	+4.1
New York, N. Y.	+1.4	Corpus Christi, Tex.	+4.6
Washington, D. C.	+1.2		

The lowest temperature recorded during the month was 32°F. on the 18th, in the 5-degree square between the 55th and 60th parallels and the 40th and 45th meridians, while the highest for the same square was 48°, occurring on four days during the first decade of the month.

FOG.

During the period from 1901 to 1906 for the month of November the average percentage of days with fog off the banks of Newfoundland was from 30 to 35, while for November, 1915, in the same region, it was observed on 12 days, a percentage of 40. In the vicinity of Cape Cod and Nantucket the amount was also considerably above the normal, while along the North Atlantic steamer routes, east of the 30th meridian, there was less fog than usual.

PRECIPITATION.

Hail was observed on 9 days during the month, north of the 40th parallel; also on the 8th and 14th, in the region between the 30th and 35th parallels, and the 50th and 60th meridians. Snow was reported on the 11th and 13th between Iceland and the Scandinavian Peninsula, and on the 17th and 19th between the 40th and 45th parallels and the 45th and 55th meridians.

Maximum wind velocities during November, 1916.

[Velocities below 50 mls./hour (22.4 m./sec.) are not included.]

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		Mls./hr.				*Mls./hr.*	
Block Island, R. I.	24	54	w.	North Head,			
Buffalo, N. Y.	10	63	sw.	Wash.	1	58	se.
Do.	23	66	sw.	Do.	2	66	s.
Do.	24	72	w.	Do.	3	70	se.
Canton, N. Y.	24	56	w.	Do.	4	60	se.
Cheyenne, Wyo.	5	68	w.	Do.	5	50	se.
Do.	9	58	w.	Do.	21	60	se.
Do.	28	54	w.	Do.	24	54	s.
Cleveland, Ohio	24	54	w.	Do.	26	76	se.
Duluth, Minn.	23	52	w.	Do.	27	78	se.
Eastport, Me.	11	50	w.	Do.	29	62	s.
Do.	24	54	s.	Point Reyes			
Erie, Pa.	23	55	sw.	Light, Cal.	6	54	nw.
Grand Haven, Mich.	24	53	w.	Do.	18	54	nw.
				Portland, Me.	11	61	nw.
Grand Junction, Colo.	5	56	w.	Do.	24	60	se.
				Do.	25	55	sw.
Key West, Fla.	15	52	n.	St. Louis, Mo.	8	58	s.
Lexington, Ky.	23	50	sw.	St. Paul, Minn.	6	56	s.
Louisville, Ky.	23	52	sw.	Do.	23	50	nw.
Modena, Utah	5	51	s.	Salt Lake City, Utah	5	50	sw.
Mount Tamalpais, Cal.	5	57	sw.	Sand Key, Fla.	15	71	n.
Do.	6	58	nw.	Sandy Hook, N. Y.	23	57	sw.
Do.	13	58	nw.	Seattle, Wash.	27	52	w.
Do.	18	53	nw.	Tatoosh Island,			
Do.	19	60	n.	Wash.	2	68	s.
New York, N. Y.	23	62	s.	Do.	27	56	w.
Do.	24	66	nw.	Do.	29	68	s.
				Wichita, Kans.	26	51	s.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November, 1916.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	54.8	+0.5	Riverton	89	5	2 stations	12	16†	2.82	−0.11	Auburn	5.68	Ashville	1.40
Arizona	48.8	−2.3	2 stations	95	1†	Fort Valley	− 1	13	0.00	−0.86	Paradise	0.11	115 stations	0.00
Arkansas	52.1	+1.1	2 stations	87	2	Dutton	10	15	2.95	−0.32	Nail	5.15	Portland	1.54
California	48.0	−4.9	Calexico	99	2	Tamarack	−12	13	1.77	−1.04	Branscomb	11.19	25 stations	0.00
Colorado	31.8	−3.4	Holly	88	5	Lay	−34	13	0.65	−0.13	Fairview	3.31	5 stations	T.
Florida	65.3	+0.1	Fenholloway	89	11	3 stations	22	17	3.72	+1.58	Brooksville No. 1	9.31	Fenholloway	1.27
Georgia	55.5	+1.1	Valdosta	90	12	Ramhurst	16	16	1.80	−0.83	Lost Mountain	4.71	Putnam	0.50
Hawaii [October]	72.8	.....	Kahuku, Oahu	95	7	Glenwood	52	3	5.59	.....	Olokele Ditch	22.35	4 stations	0.00
Idaho	30.3	−5.4	Pollock	77	3	Grays Lake	−27	12	1.67	−0.40	Elk Creek	5.77	Weston	0.05
Illinois	44.1	+3.2	2 stations	82	4	Freeport	5	14	1.97	−0.77	Minonk	2.75	Olney	1.15
Indiana	43.9	+1.8	Crawfordsville	82	8	Shelbyville	2	15	1.85	−1.18	Kokomo	4.35	2 stations	0.99
Iowa	37.3	+3.3	Sigourney	80	7	Alton	− 8	14	1.61	+0.10	Onawa	3.65	Matlock	0.05
Kansas	44.0	+0.9	Hugoton	89	5	2 stations	− 9	14	1.50	+0.33	Yates Center	4.60	13 stations	T.
Kentucky	47.8	+1.8	Beaver Dam	83	5	Anchorage	8	15	1.52	−2.07	Scott	2.25	Alpha	0.85
Louisiana	58.1	−0.5	Jennings	93	1	Newellton	16	16	1.10	−2.43	Minden	3.35	Vinton	T.
Maryland-Delaware	45.0	+0.5	Western Port, Md.	83	9	Deer Park, Md	9	16	2.19	−0.24	Princess Anne, Md.	4.60	Green Springs Furnace, Md.	1.03
Michigan	36.3	+0.6	2 stations	74	6†	Humboldt	−11	26	2.24	−0.26	Petoskey	5.01	Escanaba	0.49
Minnesota	30.9	+1.6	Lynd	75	3	Bagley	−12	25	0.45	−0.52	Grand Meadow	2.49	2 stations	0.00
Mississippi	54.6	−0.5	Shubuta	89	12	Calhoun City	12	16	1.84	−1.37	Leakesville	3.44	Austin	0.80
Missouri	46.9	+1.9	Marble Hill	85	4	Unionville	3	14	2.49	+0.14	Hollister	5.60	Patton No. 2	1.45
Montana	29.7	−2.3	Billings	76	4	Bowen	−37	12	0.70	−0.24	Haugan	3.92	Three Forks	T.
Nebraska	36.5	+0.1	Ainsworth	83	3	2 stations	−25	13	0.59	−0.08	Falls City	2.62	3 stations	0.00
Nevada	35.5	−4.0	2 stations	82	2†	2 stations	−13	13	0.34	−0.44	Marlette Lake	2.21	12 stations	0.00
New England	36.7	−0.6	2 stations	71	9	2 stations	− 7	17	2.96	−0.53	Somerset, Vt	5.56	Provincetown, Mass.	1.05
New Jersey	43.3	+0.5	2 stations	75	9	Culvers Lake	11	26	2.11	−1.29	Charlotteburg	3.81	Asbury Park	0.80
New Mexico	41.3	−1.8	Deming	92	4	Winsor's	− 8	15	0.13	−0.59	Meek	0.97	21 stations	0.00
New York	37.5	0.0	Lauterbrunnen No. 3	74	8	Wanakena	− 8	26	2.62	−0.27	North Lake	5.16	Chazy	0.67
North Carolina	50.6	+1.4	4 stations	84	5†	2 stations	11	16†	1.47	−1.22	Andrews	4.44	Lillington	0.33
North Dakota	28.9	+3.0	2 stations	75	5†	2 stations	−18	13	0.24	−0.36	Bowbells	0.86	4 stations	T.
Ohio	42.6	+1.5	Portsmouth	80	7†	Bellefontaine	5	15	2.11	−0.35	Upper Sandusky	4.10	Waverly	1.95
Oklahoma	49.9	−0.3	Weatherford	92	1	Hooker	− 2	14	2.43	+0.46	McAlester	6.93	Beaver	T.
Oregon	37.6	−4.5	Dayville	77	2	Crescent	−18	13	4.14	−0.90	Golden Falls	15.98	Prineville	0.22
Pennsylvania	41.3	+0.6	Hamburg	79	9	Lawrenceville	4	26	2.27	−0.52	Mount Pocono	7.97	2 stations	0.88
Porto Rico	76.3	−0.5	Bacupey	96	1†	Maricao	50	4†	8.62	+0.78	Carite Camp	18.47	Penuelas	2.55
South Carolina	54.5	+0.6	Blackville	88	7	Saluda	17	26	1.21	−1.09	Mountain Rest	3.23	2 stations	0.50
South Dakota	33.2	+2.5	2 stations	81	3†	Ardmore	−26	12	0.31	−0.31	Lead	1.28	8 stations	T.
Tennessee	49.3	+0.9	Arlington	87	3	3 stations	8	16†	1.90	−1.69	Copperhill	3.33	Memphis	0.86
Texas	56.0	−1.1	Fort Stockton	96	4†	Dalhart	− 4	14	1.60	−0.69	Crockett	4.20	Fort Davis	0.00
Utah	32.8	−4.9	Springdale	85	29	Blacks Fork	−28	13	0.51	−0.44	Pinecrest	3.60	15 stations	0.00
Virginia	47.2	+1.0	3 stations	80	5†	Burkes Garden	11	16	1.55	−0.78	Quantico	3.07	Woodstock	0.70
Washington	35.9	−4.5	Starbuck	73	3	2 stations	− 3	12	3.93	−1.31	Yale	16.47	Rock Island	0.36
West Virginia	43.8	+1.2	Spencer	84	12	Bayard	8	16	1.77	−0.77	Wheeling	3.07	Upper Tract	0.75
Wisconsin	32.3	−0.5	Osceola	75	6	Hillsboro	−15	14	1.69	−0.04	Manitowoc	3.52	Ashland No. 3	T.
Wyoming	26.8	−5.6	Wheatland	77	1	Soda Butte	−36	13	0.68	+0.11	Bechler River	3.37	Eden	0.00

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m., daily, 75th meridian time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sealevel and standard gravity.

Chart IV.—Temperature departures. This chart presents the departures of the monthly mean temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin "R," Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—Isobars and isotherms at sealevel and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observations, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction, t_0–t, or temperature on the sealevel plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sealevel temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—Average values of pressure, temperature, and prevailing wind directions, and storm tracks over the North Atlantic Ocean *for the corresponding month of last year*.

TABLE I.—*Climatological data for Weather Bureau stations, November, 1916.*

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | | | | | |

TABLE I.—*Climatological data for Weather Bureau stations, November, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.									Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea-level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea-level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.								
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F.	°F.		°F.	°F.	°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*									0–10	*In.*	*In.*
							47.1	+2.8												68	1.64	−1.8											3.7		
Chattanooga	762	189	213	29.39	30.22	+0.08	51.7	+1.4	79	5	62	21	15	41	36	43	37	64	2.93	−0.6	10	5,527	s.	32	sw.	23	19	6	5	3.1	T.	....
Knoxville	996	93	100	29.12	30.20	+ .07	48.8	+1.7	75	6	60	20	16	38	33	42	36	70	2.55	−1.0	9	2,856	ne.	28	sw.	9	20	3	7	3.1	T.	....
Memphis	399	76	97	29.77	30.20	+ .08	54.0	+2.6	78	6	63	24	15	45	25	45	37	59	0.86	−3.7	3	6,521	s.	42	sw.	23	20	5	5	2.7	0.0	....
Nashville	546	168	191	29.61	30.21	+ .09	50.2	+1.5	78	5	62	18	15	39	35	42	35	64	1.00	−2.8	6	6,264	se.	36	w.	23	21	6	3	2.5	T.	....
Lexington	989	193	230	29.10	30.19	+ .07	47.4	+2.7	76	6	57	14	15	38	27	....	....	....	1.25	−2.2	6	11,113	sw.	50	sw.	23	20	3	7	3.0	T.	....
Louisville	525	219	255	29.59	30.18	+ .06	48.5	+2.2	78	6	58	18	15	39	28	40	32	60	1.17	−3.0	6	9,298	s.	52	sw.	23	21	1	8	2.9	T.	....
Evansville	431	139	175	29.68	30.16	+ .04	49.5	+4.2	78	5	59	18	14	40	27	42	36	67	1.11	−3.0	5	8,531	s.	38	sw.	23	18	7	5	3.4	0.5	....
Indianapolis	822	194	230	29.23	30.13	+ .03	45.0	+3.4	76	6	55	14	15	35	31	38	32	67	1.73	−1.8	6	9,816	s.	42	nw.	23	16	6	8	3.9	0.7	....
Terre Haute	575	96	129	29.49	30.12	.....	46.0	.....	76	6	56	14	15	36	31	39	33	68	1.71	.....	6	8,132	sw.	33	w.	23	14	11	5	4.1	0.8	....
Cincinnati	628	11	51	29.46	30.16	+ .04	45.4	+5.8	75	4	56	14	15	35	34	38	32	68	1.85	−1.4	6	6,467	sw.	36	sw.	23	18	4	8	3.5	0.2	....
Columbus	824	173	222	29.25	30.15	+ .04	43.4	+2.0	72	7	53	15	15	34	31	38	33	72	1.58	−1.5	8	9,111	sw.	48	w.	24	17	4	9	3.8	0.3	....
Dayton	899	181	216	29.15	30.13	.....	43.6	+1.5	73	6	53	13	15	34	32	38	34	76	1.67	−1.2	7	8,862	sw.	42	w.	23	19	3	8	3.5	0.8	....
Pittsburgh	842	353	410	29.22	30.15	+ .05	44.5	+1.6	71	8	53	18	16	36	27	38	32	69	1.86	−0.7	8	9,157	sw.	48	w.	24	13	5	12	5.0	0.3	....
Elkins	1,940	41	50	28.09	30.20	+ .08	41.6	+2.0	75	8	55	15	16	28	43	35	31	77	1.50	−1.4	12	2,808	w.	26	w.	23	11	8	11	5.4	T.	....
Parkersburg	638	77	84	29.51	30.18	+ .06	45.5	+2.3	74	4	56	22	16	35	36	39	34	72	1.84	−1.0	5	4,393	se.	32	nw.	9	11	6	13	5.1	T.	....
Lower Lake Region.							39.9	+0.8												74	1.84	−1.2											6.2		
Buffalo	767	247	280	29.22	30.07	+0.02	39.2	−0.1	68	8	45	18	26	33	25	36	32	78	1.53	−1.8	14	15,710	w.	72	w.	24	7	7	16	6.7	8.5	....
Canton	448	10	61	29.58	30.07	.....	33.8	−0.1	68	8	42	1	26	26	29	....	....	....	1.63	−1.8	11	9,511	sw.	56	w.	24	7	10	13	6.4	3.0	....
Oswego	335	76	91	29.70	30.08	+ .04	38.6	−0.5	70	8	45	12	26	32	25	34	30	75	1.56	−1.8	14	8,923	s.	46	w.	24	2	7	21	7.6	7.7	....
Rochester	523	97	113	29.50	30.09	+ .04	39.4	+1.5	74	8	46	20	26	33	28	34	30	72	1.76	−1.0	15	6,752	sw.	44	w.	24	5	9	16	7.1	11.7	....
Syracuse	597	97	113	29.44	30.09	+ .03	38.6	−0.1	68	9	45	14	26	32	26	34	30	74	2.00	−0.7	17	9,055	s.	45	sw.	24	7	5	18	6.7	10.3	....
Erie	714	130	166	29.29	30.07	+ .01	41.3	+0.2	73	8	48	19	16	35	25	37	32	70	2.34	−1.3	13	13,384	sw.	55	sw.	23	7	7	16	6.3	12.2	....
Cleveland	762	190	201	29.26	30.10	+ .03	42.3	+1.9	71	8	49	18	16	35	26	37	33	74	2.35	−0.4	12	12,225	sw.	54	w.	24	11	4	15	5.5	10.1	....
Sandusky	629	62	103	29.40	30.10	+ .02	42.2	+1.4	74	7	50	17	15	35	25	37	33	73	2.19	−0.6	9	11,114	sw.	46	w.	24	11	7	12	5.5	0.1	....
Toledo	628	208	243	29.40	30.10	+ .03	41.7	+2.0	72	7	50	18	15	34	26	37	33	75	1.79	−0.9	10	12,341	sw.	45	sw.	10	10	7	13	5.4	0.2	....
Fort Wayne	856	113	124	29.17	30.11	.....	41.4	+0.8	73	7	50	13	15	32	36	36	32	74	1.98	.....	9	8,820	sw.	40	sw.	23	10	10	10	5.3	0.8	....
Detroit	730	218	245	29.27	30.08	+ .02	40.5	+1.9	70	7	48	16	16	34	25	36	33	78	1.21	−1.4	11	8,977	w.	44	sw.	23	8	9	13	6.0	0.5	....
Upper Lake Region.							35.7	+1.7												78	1.81	−0.6											6.9		
Alpena	609	13	92	29.35	30.03	+0.02	35.1	+1.4	64	8	41	12	26	29	30	32	30	85	2.15	−0.4	13	8,149	nw.	46	nw.	24	4	9	17	7.3	7.3	T.
Escanaba	612	54	60	29.35	30.04	+ .01	32.6	+0.9	56	6	39	9	15	26	26	29	25	76	0.49	−1.8	6	6,800	nw.	34	nw.	24	9	5	16	6.3	1.5	....
Grand Haven	632	54	92	29.35	30.05	+ .01	39.2	+1.2	70	6	45	19	25	33	30	36	32	74	2.37	−0.2	12	10,421	w.	53	w.	24	10	3	17	6.3	1.4	....
Grand Rapids	707	70	87	29.28	30.06	+ .01	39.8	+1.7	69	7	47	19	15	33	28	36	31	75	2.12	−0.4	13	5,260	w.	30	w.	24	7	5	18	7.2	1.0	....
Houghton	684	62	99	29.26	30.01	− .01	31.0	−0.5	64	6	37	10	26	26	28	....	....	....	1.17	−1.6	11	7,263	w.	38	w.	30	3	3	24	8.5	10.7	1.6
Lansing	878	11	62	29.10	30.06	.....	38.8	+2.0	71	7	48	15	16	30	28	34	31	81	1.68	−0.7	11	5,590	sw.	26	nw.	24	6	5	19	6.9	0.4	....
Ludington	637	60	66	29.33	30.04	.....	37.8	.....	67	6	43	18	26	33	27	35	32	80	2.86	.....	16	8,926	w.	41	nw.	24	7	4	19	6.9	12.7	....
Marquette	734	77	111	29.22	30.05	+ .03	32.4	+0.5	62	6	38	10	25	27	28	29	25	78	2.48	−0.3	14	7,565	w.	41	s.	6	3	8	19	7.7	11.1	0.5
Port Huron	638	70	120	29.35	30.06	+ .01	38.4	+1.6	66	7	46	15	26	31	27	35	32	81	1.08	−1.6	9	9,498	sw.	40	nw.	24	7	9	14	6.1	0.4	....
Saginaw	641	48	82	29.34	30.05	.....	38.4	.....	68	7	46	14	26	31	29	35	32	83	1.58	−0.7	10	8,031	w.	34	nw.	24	5	3	22	7.7	1.3	....
Sault Ste. Marie	614	11	61	29.31	30.03	+ .02	31.9	+1.2	52	7	37	7	25	27	28	30	28	84	2.62	−0.3	22	6,679	se.	39	nw.	10	1	3	26	9.1	14.6	0.4
Chicago	823	140	310	29.17	30.07	.00	43.2	+4.0	74	6	50	14	14	36	25	38	32	66	2.11	−0.4	5	10,242	sw.	36	s.	6	11	7	12	5.3	0.1	....
Green Bay	617	109	144	29.36	30.04	− .01	33.6	+2.5	64	6	40	2	15	27	26	30	26	79	3.27	+1.3	10	8,815	sw.	37	nw.	24	8	6	16	7.0	11.2	....
Milwaukee	681	119	133	29.30	30.05	+ .01	38.4	+5.9	63	6	45	10	14	32	24	35	31	76	2.18	+0.2	7	7,963	sw.	31	sw.	26	11	5	14	5.5	0.7	....
Duluth	1,133	111	47	28.79	30.05	+ .01	29.2	−0.1	66	6	37	0	25	21	32	25	21	76	0.09	−1.5	4	9,339	w.	52	w.	23	8	10	12	5.8	0.8	T.
North Dakota.							29.2	+4.6												73	0.18	−0.6											4.8		
Moorhead	940	8	57	29.03	30.08	+0.01	29.8	+5.4	65	3	40	0	14	20	33	26	22	81	0.10	−0.9	2	6,133	nw.	32	se.	5	16	9	5	3.8	1.0	....
Bismarck	1,674	8	57	28.26	30.11	+ .04	30.6	+4.6	67	5	43	− 5	13	18	45	25	19	70	0.13	−0.6	3	6,913	nw.	40	w.	6	12	7	11	5.0	0.8	....
Devils Lake	1,482	11	44	28.40	30.03	− .03	26.8	+4.2	59	3	37	− 4	13	17	35	23	19	79	0.12	−0.6	2	7,632	w.	38	sw.	6	12	12	6	4.7	1.5	....
Grand Forks	835	12	89	.....	.....	.....	28.0	.....	64	3	39	− 2	13	17	35	24	.....	.....	0.01	.....	1	.....	s.	46	sw.	6	18	7	5	.....	0.1	....
Williston	1,872	41	48	28.01	30.06	.00	29.6	+4.4	70	5	41	− 5	13	19	38	24	19	69	0.35	−0.2	3	5,684	w.	30	nw.	23	8	9	13	5.8	1.7	T.
Upper Mississippi Valley.							40.9	+3.2												72	1.60	−0.4											4.8		
Minneapolis	918	10	208	29.04	30.05	.....	34.6	.....	72	6	42	9	14	27	30	....	....	....	0.58	−0.6	5	7,932	nw.	43	nw.	23	8	8	14	5.7	0.1	....
St. Paul	837	201	236	29.12	30.06	0.00	33.8	+2.9	71	6	42	6	14	26	34	....	....	....	0.92	−0.4	3	8,291	nw.	56	s.	6	9	13	8	5.1	T.	....
La Crosse	714	11	48	29.26	30.06	− .01	34.0	+0.2	71	6	42	1	14	26	31	....	....	....	1.61	+0.1	8	3,946	s.	24	nw.	23	9	6	15	6.1	6.6	....
Madison	974	70	78	29.00	30.08	+ .02	35.8	+1.6	71	6	43	5	14	28	26	32	28	77	1.69	−0.1	9	8,116	nw.	34	n.	12	11	2	17	6.2	3.0	....
Wausau	1,247	4	....	28.67	30.04	.....	29.9	.....	66	6	37	− 3	15	22	31	....	....	....	1.98	.....	10	.....	nw.	....	.....	.....	9	4	17	6.5	8.5	T.
Charles City	1,015	10	49	28.97	30.08	.00	33.2	+0.2	73	6	42	− 3	14	24	31	29	27	82	1.41	0.0	8	5,046	nw.	26	sw.	6	11	8	11	5.9	7.9	....
Davenport	606	71	79	29.41	30.08	.00	41.2	+3.7	76	7	50	8	14	32	27	36	32	76	1.45	−0.3	6	5,934	sw.	29	nw.	23	13	7	10	4.9	0.1	....
Des Moines	861	84	97	29.14	30.07	− .01	39.7	+2.9	75	6	49	3	14	30	31	35	29	68	1.46	0.0	7	6,089	sw.	38	sw.	6	13	7	10	4.8	1.7	....
Dubuque	698	81	96	29.33	30.10	+ .03	37.6	+1.6	73	6	46	5	14	29	30	33	28	74	1.17	−0.6	8	4,646	nw.	31	nw.	24	12	4	14	5.6	1.1	....
Keokuk	614	64	78	29.41	30.10	+ .01	44.0	+4.6	77	7	54	10	14	34	32	38	33	72	1.75	−0.1	4	6,269	sw.	30	nw.	23	16	7	7	3.7	T.	....
Cairo	356	87	93	29.76	30.16	+ .04	50.7	+3.8	80	4	60	19	15	41	27	43	36	66	1.70	−2.3	6	5,697	s.	31	sw.	23	18	6	6	3.2	1.0	....
Peoria	609	11	45	29.42	30.10	+ .01	42.4	+4.9	76	6	52	11	14	33	32	37	33	77	1.88	−0.8	4	6,057	s.	29	w.	23	16	4	10	4.4	T.	....
Springfield, Ill	644	10	91	29.41	30.10	.00	44.6	+3.9	74	6	54	14	14	36	27	38	33	71	2.26	−0.4	5	7,277	s.	31	nw.	23	20	1	9	3.4	T.	....
Hannibal	534	74	109	29.52	30.10	+ .01	45.6	+5.1	79	5	56	12	14	35	39	....	....	....	2.01	+0.1	5	7,727	sw.	33	s.	26	19	3	8	3.5	T.	....
St. Louis	567	265	303	29.49	30.11	+ .01	49.2	+5.8	79	4	58	15	14	40	28	41	34	62	2.53	−0.4	5	11,047	s.	58	s.	8	19	4	7	3.2	0.1	....
Missouri Valley.							46.9	+3.5												68	1.38	+0.1											3.8		....
Columbia, Mo.	781	11	84	29.26	30.10	+0.01	46.4	+4.0	80	5	57	11	14	36	37	....	....	....	2.21	−0.1	6	6,874	s.	33	sw.	26	18	4	8	3.6	T.	....
Kansas City	963	161	181	29.04	30.10	+ .01	46.9	+5.4	79	5	55	13	14	39	26	39	32	62	2.83	+1.0	3	9,711	s.	39	nw.	23	19	4	7	3.8	T.	....
St. Joseph	967	11	49	29.04	30.09	.....	44.8	.....	79	3	54	12	14	36	31	38	31	67	3.11	.....	4	6,755	nw.	36	nw.	23	18	6	6	3.6	0.1	....
Springfield, Mo.	1,324	98	104	28.70	30.13	+ .03	48.3	+3.9	78	4	58	11	14	39	30	40	34	65	2.88	+0.2	6	8,462	s.	38	nw.	8	21	4	5	2.7	1.0	....
Iola	984	11	50	29.04	30.10	+ .01	46.8	+3.8	80	4	58	13	14	36	38	....	....	....	3.03	+1.6	3	6,424	s.	31	s.	7	20	3	7	3.2	T.	....
Topeka	983	85	101	.....	.....	.....	45.6	+3.9	81	3	55	12	14	36	33	....	....	....	2.65	+1.4	4	8,223	s.	39	n.	23	19	6	5	3.4	T.	....
Drexel	1,299	10	53	28.68	30.10	.....	38.3	.....	76	3	48	− 2	14	29	33	32	27	74	1.32	.....	4	8,576	sw.	33	sw.	27	16	5	9	4.2	3.5	....
Lincoln	1,189	11	84	28.80	30.10	+ .02	40.1	+2.1	78	3	50	2	14	30	37	33	27	65	0.38	−0.5	4	8,188	n.	39	nw.	23	19	5	6	3.6	2.3	....
Omaha	1,105	115	122	28.89	30.10	+ .02	40.6	+2.9	78	3	49	3	14	32	30	34	28	67	0.73	−0.3	5	6,715	nw.	37	nw.	23	17	5	8	3.8	3.2	....
Valentine	2,598	47	54	27.35	30.14	+ .06	34.6	+0.9	79	3	48	− 8	14	22	38	28	23	72	0.24	−0.5	4	6,627	w.	32	nw.	23	13	10	7	4.1	2.4	....
Sioux City	1,135	94	164	28.85	30.10	+ .02	36.5	+2.2	71	5	46	− 1	14	27	34	32	27	73	1.05	+0.1	5	8,053	nw.	48	s.	6	19	3	8	3.5	7.6	....
Huron	1,306	59	74	28.68	30.12	+ .04	33.0	+5.6	70	5	46	− 2	14	20	41	26	21	69	0.05	−0.5	4	7,301	nw.	35	nw.	23	16	7	7	4.3	0.4	....
Pierre	1,572	70	75	28.41	30.13	+ .05	35.4	+3.8	74	5	48	− 3	13	23	42	29	23	67	0.08	−0.4	3	5,600	nw.	42	w.	6	12	10	8	4.8	0.7	....
Yankton	1,233	49	57	28.75	30.10	+ .02	36.6	+3.1	70	3	47	− 2	14	26	35	....	....	....	0.39	−0.4	3	5,367	w.	36	s.	6	16	8	6	4.3	2.5	....

TABLE I.—*Climatological data for Weather Bureau stations, November, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea-level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.							
																								Miles per hour.	Direction.	Date.					
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Northern Slope.							**30.4**	**−1.6**											**66**	**0.89**	**−0.2**									**4.6**		
Billings	3,140	5					32.8		76	4	45	−19	13	21	52					0.62								17	8	5			
Havre	2,505	11	44	27.37	30.08	+0.05	31.5	+0.9	70	4	42	−21	13	21	48	28	24	76	0.46	−0.3	3	7,308	sw.	36	sw.	2	13	8	9	5.4	4.2	
Helena	4,110	87	114	25.88	30.21	+ .11	29.0	−3.7	67	4	38	−12	12	20	36	23	15	61	0.32	−0.4	5	5,387	sw.	36	sw.	28	11	10	9	5.2	3.5	T.
Kalispell	2,962	11	34	27.06	30.23	+ .16	28.0	−4.0	60	4	37	− 3	12	19	28	24	20	76	0.80	−1.1	12	2,865	w.	24	sw.	9	7	12	11	6.2	4.0	0.5
Miles City	2,371	26	48	27.54	30.16	+ .09	35.4	+4.5	72	5	47	−12	13	24	44	29	24	70	0.39	−0.2	7	4,391	se.	30	sw.	6	17	10	3	3.1	1.7	
Rapid City	3,259	50	58	26.66	30.17	+ .09	35.5	+1.9	70	5	48	−13	13	23	43	28	18	54	0.51	0.0	6	6,081	w.	39	nw.	23	13	10	7	4.6	4.7	
Cheyenne	6,088	84	101	24.63	30.17	+ .10	31.2	−3.7	67	5	42	−21	13	20	38	24	14	52	0.88	+0.5	7	11,186	w.	68	w.	5	19	3	8	3.6	12.1	
Lander	5,372	60	68	24.70	30.20	+ .10	21.4	−5.3	65	3	38	−25	13	8	46	17	10	62	0.82	+0.2	2	2,834	sw.	44	sw.	5	13	13	4	4.4	8.4	0.6
Sheridan	3,790	10	47	26.16	30.19		28.9		69	5	43	−27	13	14	51	23	18	71	0.90		8	3,879	nw.	48	sw.	5	14	10	6	4.2	8.8	T.
Yellowstone	6,200	11	48	23.94	30.28	+ .17	23.4	−5.9	59	3	34	−20	13	13	37	19	13	68	0.69	−0.8	13	6,392	s.	38	s.	27	10	7	13	5.9	9.4	3.8
North Platte	2,821	11	51	27.17	30.18	+ .10	35.8	+0.7	78	3	49	− 5	14	22	44	28	22	70	0.47	+0.1	5	5,157	w.	28	nw.	23	17	5	8	3.7	3.6	
Middle Slope.							**42.8**	**+1.1**											**65**	**1.16**	**+0.2**									**3.0**		
Denver	5,292	106	113	24.78	30.16	+0.10	38.1	−1.1	76	5	50	− 3	13	26	38	29	19	56	0.66	+0.1	9	5,755	se.	31	se.	5	20	5	5	3.1	10.2	
Pueblo	4,685	80	86	25.35	30.14	+ .09	38.3	−1.0	79	5	54	− 8	14	23	50	29	19	56	0.20	−0.2	4	4,771	nw.	36	nw.	9	23	4	3	2.2	3.4	
Concordia	1,392	50	58	28.61	30.12	+ .04	42.8	+2.9	81	3	54	6	14	31	36	35	29	69	0.77	−0.2	3	6,575	nw.	33	s.	5	15	10	5	3.9	4.4	
Dodge City	2,509	11	51	27.48	30.14	+ .07	42.0	+1.5	85	5	57	2	13	27	50	34	28	69	0.03	−0.5	1	7,398	n.	38	s.	26	21	5	4	2.7	0.3	
Wichita	1,359	139	158	28.64	30.10	+ .02	46.2	+2.4	79	3	56	12	14	36	29	39	34	68	2.93	+1.8	4	10,885	s.	51	s.	26	20	4	6	3.2	T.	
Altus	1,410	5					50.4		84	1	64	14	14	37	41				1.99		3		n.				23	0	7		0.0	
Muskogee	652	4					50.2		81	3	62	15	24	39	41				3.34		5		s.				19	2	9		0.0	
Oklahoma	1,214	10	47	28.83	30.14	+ .06	49.7	+1.8	83	2	61	14	14	38	36	41	35	70	2.35	+0.1	5	11,871	s.	44	s.	7	22	5	3	2.6	0.1	
Southern Slope.							**49.7**	**−1.3**							**43**				**0.48**	**−0.7**										**2.6**		
Abilene	1,738	10	52	28.30	30.14	+0.07	52.1	−0.5	84	1	65	16	14	39	39	42	34	61	0.88	−0.4	4	8,057	s.	38	s.	7	22	4	4	2.5	0.2	
Amarillo	3,676	10	49	26.34	30.13	+ .08	44.4	+0.6	85	4	58	5	14	30	42	35	27	63	0.40	−0.8	3	8,233	sw.	35	n.	11	23	3	4	3.0	3.7	
Del Rio	944	64	71	29.13	30.13	+ .08	57.7	−1.6	83	1	70	25	16	46	39				0.21	−1.0	2	7,222	e.	40	nw.	21	17	9	4	3.0	0.0	
Roswell	3,566	75	85	26.46	30.14	+ .11	44.5	−3.6	87	5	61	6	14	28	52	34	23	54	0.44	−0.7	2	4,833	n.	31	sw.	7	24	3	3	1.7	3.4	
Southern Plateau.							**47.2**	**−1.8**											**43**	**0.12**	**−0.5**									**1.6**		
El Paso	3,762	110	133	26.27	30.07	+0.07	51.2	+0.3	84	4	66	18	15	37	38	38	24	39	0.52	−0.1	1	7,108	nw.	43	ne.	21	27	2	1	1.2	T.	
Santa Fe	7,013	57	66	23.28	30.10	+ .07	38.9	+0.7	68	2	51	10	14	27	31	28	17	47	0.06	−0.7	1	5,586	e.	37	sw.	12	20	10	0	2.0	1.4	
Flagstaff	6,908	8	57	23.40	30.10	+ .08	34.4	−0.2	73	1	51	6	13	18	47	25			0.00		0		w.	44	sw.	5	24	6	0			
Phoenix	1,108	76	81	28.88	30.05	+ .07	55.8	−2.9	88	2	74	28	14	37	44	42	32	52	0.00	−1.0	0	3,364	e.	20	e.	15	28	2	0	1.0	0.0	
Yuma	141	9	54	29.89	30.04	+ .06	60.0	−1.9	90	1	75	36	22	45	40	45	28	35	0.00	−0.3	0	4,423	n.	33	n.	13	28	2	0	0.6	0.0	
Independence	3,910	11	42	26.06	30.12	+ .07	42.7	−6.5	73	1	60	16	13	26	43				0.00	−0.3	0	4,166	s.	32	w.	5	22	5	3	3.3	0.0	
Middle Plateau.							**35.2**	**− 4.3**											**54**	**0.32**	**− 0.6**									**2.9**		
Reno	4,532	74	81	25.60	30.24	+0.13	37.6	− 3.4	76	2	52	8	14	23	43	29	19	52	0.05	− 1.0	2	4,257	w.	38	w.	26	22	6	2	2.5	T.	
Tonopah	6,090	12	20	24.16	30.20		37.2		66	2	46	6	13	29	24	29	18	48	0.09	− 0.8	2	6,475	w.	43	nw.	5	21	7	2	2.3	0.9	
Winnemucca	4,344	18	56	25.77	30.28	+ .14	33.0	− 4.5	74	2	49	− 3	13	17	47	25	17	59	0.44	− 0.3	5	4,620	ne.	33	sw.	4	18	4	8	3.2	0.1	
Modena	5,479	10	43	24.72	30.20	+ .12	33.6	− 5.4	74	2	50	5	14	17	45	24	12	48	0.07	− 0.5	1	7,096	w.	51	s.	5	21	6	3	2.4	0.3	
Salt Lake City	4,360	147	189	25.77	30.24	+ .12	36.2	− 4.2	70	3	45	9	13	28	27	30	22	59	0.92	− 0.5	6	4,447	se.	50	sw.	5	14	5	11	4.4	5.0	T.
Grand Junction	4,602	82	96	25.50	30.16	+ .08	35.8	− 4.1	69	5	48	6	13	23	37	28	20	57	0.34	− 0.2	2	4,256	se.	56	w.	5	19	8	3	2.6	4.8	
Northern Plateau.							**34.3**	**− 4.4**											**66**	**1.29**	**− 0.1**									**5.8**		
Baker	3,471	48	53	26.60	30.27	+0.11	31.2	− 3.7	64	2	42	− 4	13	21	33	27	20	64	0.35	− 0.8	4	4,851	se.	30	se.	4	12	9	9	5.1	2.0	
Boise	2,739	78	86	27.36	30.30	+ .13	36.5	− 3.1	70	3	46	7	13	27	29	30	21	55	1.07	+ 0.2	7	3,684	se.	24	se.	27	13	5	12	4.9	0.2	
Lewiston	757	40	48	29.43	30.26	+ .14	37.0	− 3.9	62	3	46	9	13	28	32				1.37	0.0	10	2,164	e.	22	w.	9	7	7	16	6.5	0.4	
Pocatello	4,477	60	68	25.61	30.26	+ .12	31.5	− 4.8	68	2	42	− 1	12	21	34	26	20	65	0.61	+ 0.1	6	7,024	se.	40	sw.	9	13	6	11	5.2	5.0	
Spokane	1,929	101	110	28.13	30.25	+ .15	33.1	− 4.2	57	3	40	5	13	26	27	30	25	72	1.60	− 0.7	11	4,021	ne.	32	sw.	9	6	8	16	6.8	5.8	
Walla Walla	991	57	65	29.16	30.27	+ .14	36.5	− 6.4	69	3	43	12	13	30	26	33	29	75	2.74	+ 0.6	9	3,431	sw.	28	w.	9	8	5	17	6.6	0.0	
North Pacific Coast Region.							**43.4**	**− 2.1**											**80**	**5.90**	**− 1.4**									**6.1**		
North Head	211	11	56	29.92	30.15	+0.10	45.2	− 2.5	58	20	49	31	12	41	18	43	40	83	6.75	+ 0.4	17	12,738	se.	78	se.	27	10	4	16	5.8	0.0	
North Yakima	1,076	4					34.6		66	9	45	6	13	24	36				0.40		4		se.				11	8	11		0.6	
Seattle	125	215	250	30.06	30.19	+ .15	43.0	− 1.5	55	1	48	29	12	38	23	40	36	79	4.58	− 1.3	14	6,513	s.	52	w.	27	6	7	17	6.9	0.0	
Tacoma	213	113	120	29.95	30.19	+ .15	41.8	− 2.3	56	2	48	23	13	36	24	40	37	83	5.49	− 3.0	12	4,279	sw.	29	s.	4	6	10	14	6.6	0.0	
Tatoosh Island	109	7	57	30.02	30.11	+ .14	44.2	− 1.7	52	6	47	35	12	41	11	42	39	83	7.62	− 4.5	20	13,896	e.	68	s.	29	9	8	13	5.8	0.0	
Medford	1,425	4					41.0		68	3	52	19	14	30	41				1.99		8		nw.				3	3	14		0.0	
Portland, Oreg.	153	68	106	30.04	30.20	+ .10	43.7	− 1.9	58	3	49	29	13	38	18	40	33	70	6.31	− 0.2	15	5,198	se.	30	sw.	27	16	5	19	6.6	0.0	
Roseburg	510	9	57	29.66	30.23	+ .11	42.8	− 2.8	67	3	52	18	13	34	31	39	36	79	4.62	+ 0.2	13	1,822	s.	23	sw.	27	9	11	10	5.1	0.0	
Middle Pacific Coast Region.							**50.2**	**− 2.8**											**63**	**1.46**	**− 1.7**									**3.6**		
Eureka	62	73	89	30.14	30.21	+0.10	47.5	− 3.5	64	2	54	31	19	41	26	45	42	82	3.13	− 2.5	12	4,275	se.	33	n.	11	12	7	11	4.7	0.0	
Mount Tamalpais	2,375	11	18	27.68	30.18	+ .09	47.6	− 3.0	64	1	53	34	13	42	18	40	27	53	1.95	− 1.7	6	14,223	ne.	60	n.	19	17	6	7	4.0	0.0	
Point Reyes Light	490	7	18	29.60	30.12		51.6	− 1.4	65	15	56	42	13	47	18				0.95		7	12,182	n.	54	nw.	18	16	7	7	4.0	0.0	
Red Bluff	332	50	56	29.82	30.18	+ .07	49.6	− 3.8	73	10	60	29	14	39	40	42	30	53	1.28	− 1.9	5	4,688	nw.	33	nw.	11	17	7	6	3.2	0.0	
Sacramento	69	106	117	30.10	30.17	+ .08	50.5	− 2.9	72	2	61	30	14	40	31	44	35	62	0.49	− 1.7	4	5,284	nw.	33	nw.	19	18	8	4	3.2	0.0	
San Francisco	155	209	213	30.00	30.17	+ .08	54.4	− 1.1	73	10	62	44	13	47	23	47	40	67	1.50	− 1.0	5	4,508	ne.	27	sw.	2	19	6	5	3.2	0.0	
San Jose	141	12	110	30.01	30.16		50.6	− 3.8	75	2	64	27	14	38	38				0.41	− 1.5	3	3,945	nw.	26	n.	12	23	2	5	2.8	0.0	
South Pacific Coast Region.							**55.4**	**− 1.6**											**64**	**0.20**	**− 1.1**									**2.3**		
Fresno	327	89	98	29.81	30.17	+0.11	51.2	− 3.4	79	2	63	28	13	40	33	44	37	63	0.28	− 0.8	3	3,163	nw.	26	nw.	4	20	6	4	3.0	0.0	
Los Angeles	338	159	191	29.73	30.10	+ .08	59.4	+ 1.0	81	10	70	41	28	49	30	49	39	57	0.09	− 1.4	1	3,765	ne.	19	nw.	7	22	6	2	2.1	0.0	
San Diego	87	62	70	29.98	30.07	+ .05	56.5	− 2.5	74	10	65	39	14	48	29	50	46	74	0.05	− 0.8	1	3,380	nw.	19	w.	5	20	10	0	2.2	0.0	
San Luis Obispo	201	32	40	29.93	30.15	+ .09	54.6	− 1.7	84	1	69	32	21	40	45	46	39	64	0.38	− 1.3	2	2,677	n.	23	n.	28	23	4	3	2.7	0.0	
West Indies.																																
San Juan, P. R	82	8	54	29.85	29.93	+0.03	77.5		89	3	82	70	24	73	14				8.15	+ 1.2	25	9,219	e.	48	ne.	1	11	12	7	5.4	0.0	
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86		77.9		89	27	84	69	2	72	17	74	73	92	8.77	− 1.4	25	4,483	s.	30	s.	13	0	9	21	7.9	0.0	
Colon	25	5	71	29.82	29.84		79.8		90	11	85	72	3	74	15	75	74	88	14.08	− 7.4	23	6,910	se.	38	w.	16	1	10	19	7.8	0.0	

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1916, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	21			0.77														0.35			
Albany, N. Y	30			0.74														0.22			
Alpena, Mich	8-9			0.57														*			
Amarillo, Tex	21			0.34														*			
Anniston, Ala	23			0.77														0.54			
Asheville, N. C	23			0.34														0.22			
Atlanta, Ga	23			0.48														0.26			
Atlantic City, N. J	12			0.69														0.24			
Augusta, Ga	28			0.53														0.25			
Baker, Oreg	25			0.22														*			
Baltimore, Md	12			0.66														0.34			
Bentonville, Ark	21			0.89														0.43			
Binghamton, N. Y	1			0.43														0.43			
Birmingham, Ala	23			0.71														0.51			
Bismarck, N. Dak	20			0.07														*			
Block Island, R. I	23			1.02														0.58			
Boise, Idaho	26			0.56														0.12			
Boston, Mass	30			0.92														0.16			
Buffalo, N. Y	9			0.40														0.12			
Burlington, Vt	23-24			0.60														*			
Cairo, Ill	9			0.91														0.30			
Canton, N. Y	23			0.51														*			
Charles City, Iowa	7-8			0.82														*			
Charleston, S. C	29			0.51														0.33			
Charlotte, N. C	23			0.18														0.11			
Chattanooga, Tenn	23			0.91														0.29			
Cheyenne, Wyo	10-11			0.35														*			
Chicago, Ill	8			0.81														0.22			
Cincinnati, Ohio	23			1.06														0.26			
Cleveland, Ohio	23			0.48														0.23			
Columbia, Mo	8			1.25														0.39			
Columbia, S. C	11			0.24														0.11			
Columbus, Ohio	23			0.80														0.17			
Concord, N. H	29-30			0.99														*			
Concordia, Kans	7	5:27 p. m.	6:38 p. m.	0.33	6:22 p. m.	6:27 p. m.	0.02	0.30													
Corpus Christi, Tex	9			0.50														0.23			
Dallas, Tex	21			1.89														0.44			
Davenport, Iowa	22			0.50														0.17			
Dayton, Ohio	22-23			0.70														*			
Del Rio, Tex	21			0.14														0.09			
Denver, Colo	20			0.25														*			
Des Moines, Iowa	7-8			1.01														0.24			
Detroit, Mich	23			0.52														0.12			
Devils Lake, N. Dak	20			0.11														*			
Dodge City, Kans	12			0.03														*			
Dubuque, Iowa	8			0.55														*			
Duluth, Minn	20			0.04														*			
Eastport, Me	24			0.57														0.17			
Elkins, W. Va	23			0.51														0.21			
El Paso, Tex	21			0.52														0.24			
Erie, Pa	9			0.40														0.13			
Escanaba, Mich	23			0.23														*			
Eureka, Cal	25			1.56														0.22			
Evansville, Ind	22			0.37														0.20			
Flagstaff, Ariz	‡			(‡)																	
Fort Smith, Ark	21			1.63														0.41			
Fort Wayne, Ind	9			0.76														*			
Fort Worth, Tex	21			1.40														0.48			
Fresno, Cal	5			0.16														0.09			
Galveston, Tex	22			1.15														0.59			
Grand Haven, Mich	8			0.93														0.35			
Grand Junction, Colo	7			0.19														0.10			
Grand Rapids, Mich	8			0.76														0.15			
Green Bay, Wis	22-23			0.80														*			
Hannibal, Mo	8			0.77														0.28			
Harrisburg, Pa	29			0.55														0.23			
Hartford, Conn	30			0.89														0.36			
Hatteras, N. C	23			0.45														0.34			
Havre, Mont	9-10			0.44														*			
Helena, Mont	9-10			0.27														*			
Houghton, Mich	14-15			0.36														*			
Houston, Tex	22	D. N. a. m.	7:45 a. m.	1.30	3:23 a. m.	4:00 a. m.	0.01	0.11	0.36	0.41	0.41	0.47	0.55	0.71	0.76						
Huron, S. Dak	11			0.02														*			
Independence, Cal	‡			‡																	
Indianapolis, Ind	23			0.89														0.29			
Iola, Kans	8			1.81														0.31			
Jacksonville, Fla	14-15			2.12														0.33			
Kalispell, Mont	25-26			0.28														*			
Kansas City, Mo	8			1.88														0.36			
Keokuk, Iowa	8			0.94														*			
Key West, Fla	24	D. N. a. m.	D. N. a. m.	0.77	12:46 a. m.	1:33 a. m.	0.03	0.14	0.25	0.30	0.35	0.37	0.44	0.49	0.60	0.67	0.73				
Knoxville, Tenn	23			0.86														0.27			
La Crosse, Wis	8			0.54														0.25			
Lander, Wyo	10			0.54														*			
Lansing, Mich	22-23			0.65														*			
Lewistown, Idaho	27			0.20														0.11			
Lexington, Ky	23			0.63														0.14			
Lincoln, Nebr	7			0.20														*			
Little Rock, Ark	28			0.59														0.45			
Los Angeles, Cal	5			0.09														0.04			
Louisville, Ky	22			0.37														0.25			
Ludington, Mich	3			0.27														0.17			
Lynchburg, Va	29			0.64														0.48			
Macon, Ga	23			0.26														0.15			
Madison, Wis	7			0.18														0.10			
Marquette, Mich	7			0.44														0.14			
Memphis, Tenn	22			0.50														0.19			
Meridian, Miss	22-23	1:54 p. m.	D. N. a. m.	2.08	7:33 p. m.	8:52 p. m.	0.22	0.09	0.19	0.40	0.67	0.77	0.87	0.96	1.04	1.17	1.26	1.37	1.60		
Miami, Fla	15			0.92														0.48			

* Self-Register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1916, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Milwaukee, Wis	8–9			0.98														*			
Minneapolis, Minn	7–8			0.42														*			
Mobile, Ala	22–23	6:10 p. m.	D. N. a. m.	1.15	10:46 p. m.	11:13 p. m.	0.48	0.06	0.09	0.14	0.32	0.50	0.54								
Modena, Utah	5			0.07														*			
Montgomery, Ala	28			2.30														0.59			
Moorhead, Minn	20			0.08														*			
Mount Tamalpais, Cal	4			0.47														0.15			
Nantucket, Mass	23–24			0.68														0.37			
Nashville, Tenn	9			0.30														0.17			
New Haven, Conn	30			0.95														0.39			
New Orleans, La	22			0.44														0.20			
New York, N. Y	30			0.40														0.18			
Norfolk, Va	14			0.51														0.15			
Northfield, Vt	23–24			0.94														*			
North Head, Wash	3			1.42														0.43			
North Platte, Nebr	10–11			0.20														*			
Oklahoma, Okla	21			1.48														0.27			
Omaha, Nebr	7–8			0.22														*			
Oswego, N. Y	4–5			0.38														*			
Palestine, Tex	21–22	8:40 a. m.	12:25 p. m.	2.19	11:06 p. m.	11:24 p. m.	0.70	0.22	0.41	0.60	0.65										
Parkersburg, W. Va	23			0.76														0.22			
Pensacola, Fla	22–23	10:20 p. m.	4:35 a. m.	1.32	12:53 a. m.	1:27 a. m.	0.11	0.32	0.59	0.66	0.78	0.82	0.92	0.97							
	28	12:50 a. m.	10:20 a. m.	1.29	7:52 a. m.	8:08 a. m.	0.67	0.11	0.34	0.50	0.51										
Peoria, Ill	22–23			1.05														0.19			
Philadelphia, Pa	30			0.48														0.15			
Phoenix, Ariz	‡			‡																	
Pierre, S. Dak	9			0.03														0.01			
Pittsburgh, Pa	4			0.42														0.17			
Pocatello, Idaho	5			0.18														*			
Point Reyes Light, Cal	4			0.31														0.10			
Port Angeles, Wash	2			0.53														0.15			
Port Huron, Mich	23			0.43														0.10			
Portland, Me	23			0.70														0.14			
Portland, Oreg	27			0.99														0.31			
Providence, R. I	23			0.67														*			
Pueblo, Colo	12			0.09														*			
Raleigh, N. C	14			0.50														0.37			
Rapid City, S. Dak	9–10			0.30														*			
Reading, Pa	30			0.55														0.32			
Red Bluff, Cal	25			0.99														0.26			
Reno, Nev	25			0.04														*			
Richmond, Va	30			0.36														0.27			
Rochester, N. Y	4			0.24														0.13			
Roseburg, Oreg	25			1.65														0.25			
Roswell, N. Mex	21			0.42														*			
Sacramento, Cal	25			0.36														0.11			
Saginaw, Mich	8–9			0.60														*			
St. Joseph, Mo	8			2.06														0.61			
St. Louis, Mo	8			0.63														0.33			
St. Paul, Minn	7–8			0.82														*			
Salt Lake City, Utah	5			0.33														*			
San Antonio, Tex	21			0.60														0.47			
San Diego, Cal	7			0.05														0.04			
Sand Key, Fla	15			0.82														0.69			
Sandusky, Ohio	9			0.53														0.20			
Sandy Hook, N. J	30			0.62														*			
San Francisco, Cal	25			0.57														0.20			
San Jose, Cal	5			0.22														0.17			
San Luis Obispo, Cal	4			0.24														0.14			
Santa Fe, N. Mex	8			0.06														*			
Sault Ste. Marie, Mich	23–24			0.44														*			
Savannah, Ga	30			0.24														0.21			
Scranton, Pa	1			0.48														0.42			
Seattle, Wash	3			1.06														0.28			
Sheridan, Wyo	9–10			0.55														*			
Shreveport, La	21–22	5:15 p. m.	1:30 p. m.	2.13	4:10 a. m.	4:42 a. m.	0.58	0.15	0.21	0.26	0.35	0.45	0.54	0.58							
Sioux City, Iowa	11–12			0.39														*			
Spokane, Wash	25			0.56														*			
Springfield, Ill	8			0.70														0.28			
Springfield, Mo	8			0.94														0.35			
Syracuse, N. Y	4–5			0.46														*			
Tacoma, Wash	27			1.26														0.24			
Tampa, Fla	15			2.79														0.67			
Tatoosh Island, Wash	4			0.87														0.24			
Taylor, Tex	21			0.75														0.28			
Terre Haute, Ind	9			0.68														0.16			
Thomasville, Ga	23	D. N. a. m.	9:50 a. m.	1.31	6:39 a. m.	7:09 a. m.	0.15	0.16	0.30	0.47	0.51	0.57	0.63								
Toledo, Ohio	3			0.36														0.21			
Tonopah, Nev	5			0.06														*			
Topeka, Kans	8			2.11														0.59			
Valentine, Nebr	10–11			0.17														*			
Vicksburg, Miss	22			0.78														0.31			
Walla Walla, Wash	4			0.74														0.25			
Washington, D. C	30			0.96														0.71			
Wichita, Kans	7–8			2.73														0.61			
Williston, N. Dak	20			0.18														*			
Wilmington, N. C	29			0.82														0.34			
Winnemucca, Nev	25			0.25														0.17			
Wytheville, Va	12			0.23														0.12			
Yankton, S. Dak	11			0.19														*			
Yellowstone Park, Wyo	27–28			0.20														*			

*Self-register not in use. †Record partly estimated. ‡No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, November, 1916.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea-level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.65	29.79	−0.15	33.9	− 2.6	39.2	28.7	54	16	3.27	−2.30	11.0
Sydney, C. B. I.	48	29.94	*29.98*	+ .03	36.0	− 1.1	41.9	30.2	56	16	3.39	−2.05	13.5
Halifax, N. S.	88	29.92	*30.03*	+ .02	36.4	− 0.9	44.3	28.6	60	11	2.07	−3.59	1.5
Yarmouth, N. S.	65	29.97	30.04	+ .02	38.3	− 1.6	43.9	32.6	56	16	2.17	−2.39	2.5
Charlottetown, P. E. I.	38	29.94	29.98	+ .02	33.4	− 2.1	38.2	28.6	53	13	3.64	−0.33	11.7
Chatham, N. B.	28	29.98	*30.00*	+ .03	30.1	− 0.9	37.2	23.0	64	3	2.82	−0.93	10.2
Father Point, Que.	20	29.96	29.98	+ .02	28.1	− 0.8	33.1	23.2	55	7	3.68	+0.57	8.6
Quebec, Que.	296	29.70	30.04	+ .02	28.4	− 0.6	34.5	22.2	63	− 4	4.02	+0.26	8.8
Montreal, Que.	187	29.83	30.05	+ .02	32.1	+ 0.3	38.4	25.8	64	2	2.75	−0.99	3.4
Stonecliffe, Ont.	489	29.40	*30.03*	+ .02	29.4	+ 0.3	37.3	21.5	68	−10	1.57	−1.01	1.4
Ottawa, Ont.	236	29.78	*30.12*	+ .10	31.7	0.0	38.7	24.7	63	− 1	2.40	−0.14	4.4
Kingston, Ont.	285	29.75	30.07	+ .03	36.6	+ 1.6	42.6	30.7	58	9	1.91	−1.33	3.1
Toronto, Ont.	379	29.65	*30.04*	.00	37.6	+ 2.0	44.5	30.7	64	12	1.64	−1.50	6.4
White River, Ont.	1,244	28.61	*29.97*	− .01	21.0	+ 0.5	29.9	12.1	52	−27	1.17	−0.68	9.7
Port Stanley, Ont.	592	29.44	30.10	+ .05	38.4	+ 1.6	45.4	31.4	59	13	2.23	−1.14	1.7
Southampton, Ont.	656	29.31	.....	.....	36.5	+ 1.5	42.7	30.2	65	11	4.01	+0.31	22.3
Parry Sound, Ont.	688	29.31	30.02	+ .01	33.4	+ 1.3	40.4	26.5	63	− 3	4.53	+0.16	8.0
Port Arthur, Ont.	644	29.29	30.02	+ .02	28.0	+ 4.0	36.0	20.0	55	− 2	0.13	−1.20	1.0
Winnipeg, Man.	760	29.14	30.00	− .04	27.0	+ 9.0	34.7	19.2	57	0	0.32	−0.76	1.1
Minnedosa, Man.	1,690	28.11	29.98	− .06	24.8	+ 7.5	32.9	16.8	58	− 2	0.10	−0.90	1.0
Qu'Appelle, Sask.	2,115	27.63	29.93	− .07	26.0	+ 7.2	34.2	17.8	57	− 6	0.15	−0.74	1.5
Medicine Hat, Alberta.	2,144	27.65	*29.97*	− .03	33.3	+ 5.9	43.2	23.4	68	−12	0.55	−0.37	5.5
Swift Current, Sask.	2,392	27.34	*29.98*	− .04	27.6	+ 4.4	38.1	17.2	61	−13	0.62	−0.07	6.2
Calgary, Alberta.	3,428	26.38	*30.00*	+ .02	31.1	+ 5.3	41.8	20.4	56	−10	0.28	−0.60	2.8
Banff, Alberta.	4,521	25.37	*30.11*	+ .15	22.6	− 3.2	29.8	15.5	40	−21	1.24	−1.03	9.2
Edmonton, Alberta.	2,150	27.58	*29.92*	− .05	28.7	+ 5.8	37.7	19.8	52	− 8	0.71	+0.13	7.0
Prince Albert, Sask.	1,450	28.33	*29.93*	− .10	25.3	+ 9.9	34.7	16.0	58	− 4	0.65	−0.18	6.5
Battleford, Sask.	1,592	28.17	*29.96*	− .06	27.2	+10.9	36.5	18.0	61	0	T.	−0.58	T.
Kamloops, B. C.	1,262	28.89	30.22	+ .26	30.8	− 2.6	37.4	24.3	57	5	0.64	−0.82	1.8
Victoria, B. C.	230	29.89	30.15	+ .16	42.3	− 0.9	46.4	38.1	52	29	2.26	−4.71	0.0
Barkerville, B. C.	4,180	25.66	30.08	+ .18	22.1	− 1.5	29.3	14.9	39	−13	4.97	+1.68	49.7
Hamilton, Bermuda.	151	29.97	30.13	+ .08	67.9	− 0.8	72.9	63.0	79	52	7.00	+2.62	0.0

* The altitudes given above were furnished by the Director of the Canadian Meteorological Service Mar. 9, 1916, and refer to cisterns of barometers at the respective stations. Where sealevel pressures and departures are *italicized* new reduction factors are in course of computation.—C. A., jr.

Chart I. Hydrographs of Several Principal Rivers, November, 1916.

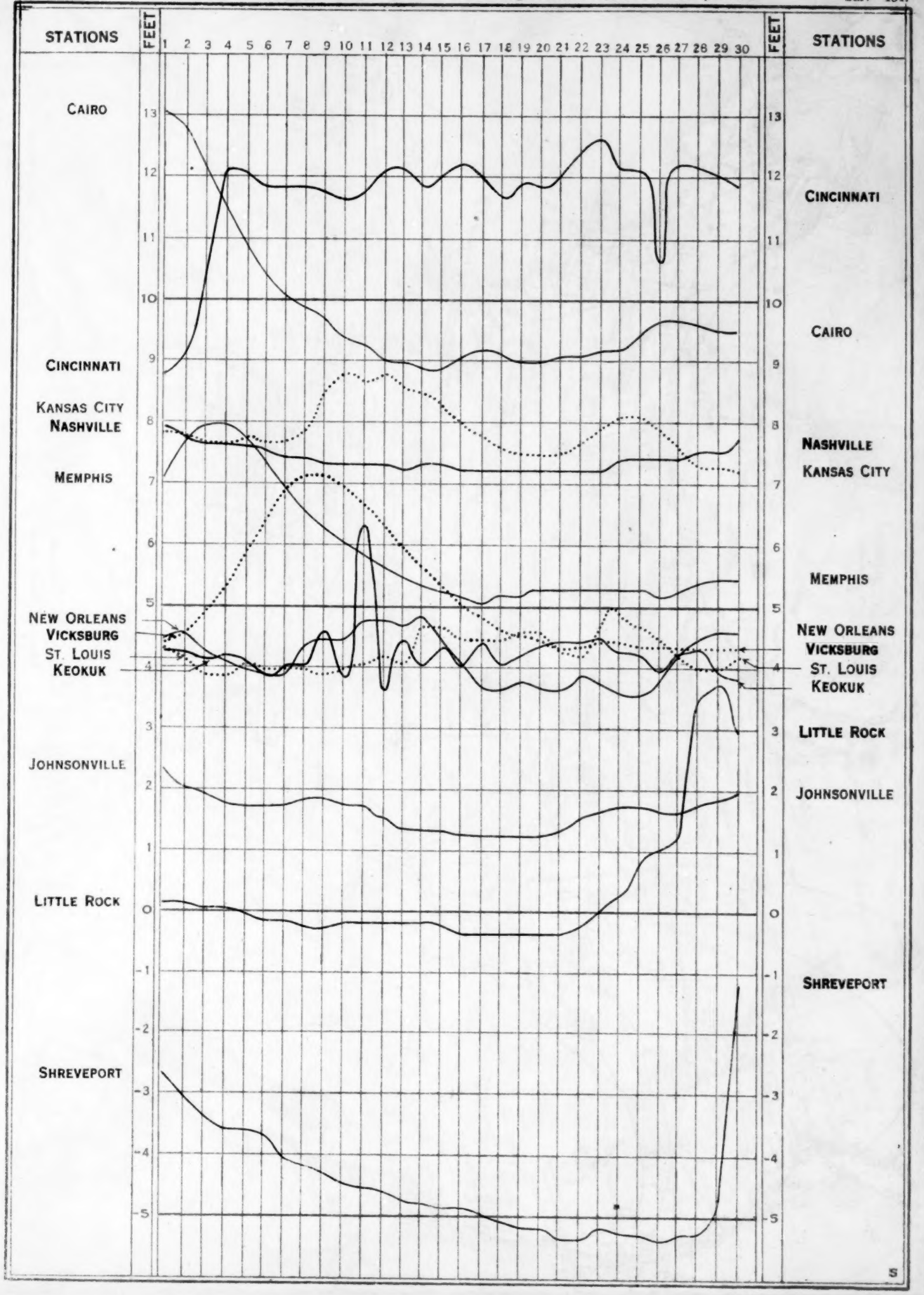


Chart II. Tracks of Centers of High Areas, November, 1916.

(Plotted by Charles A. Donnel.)

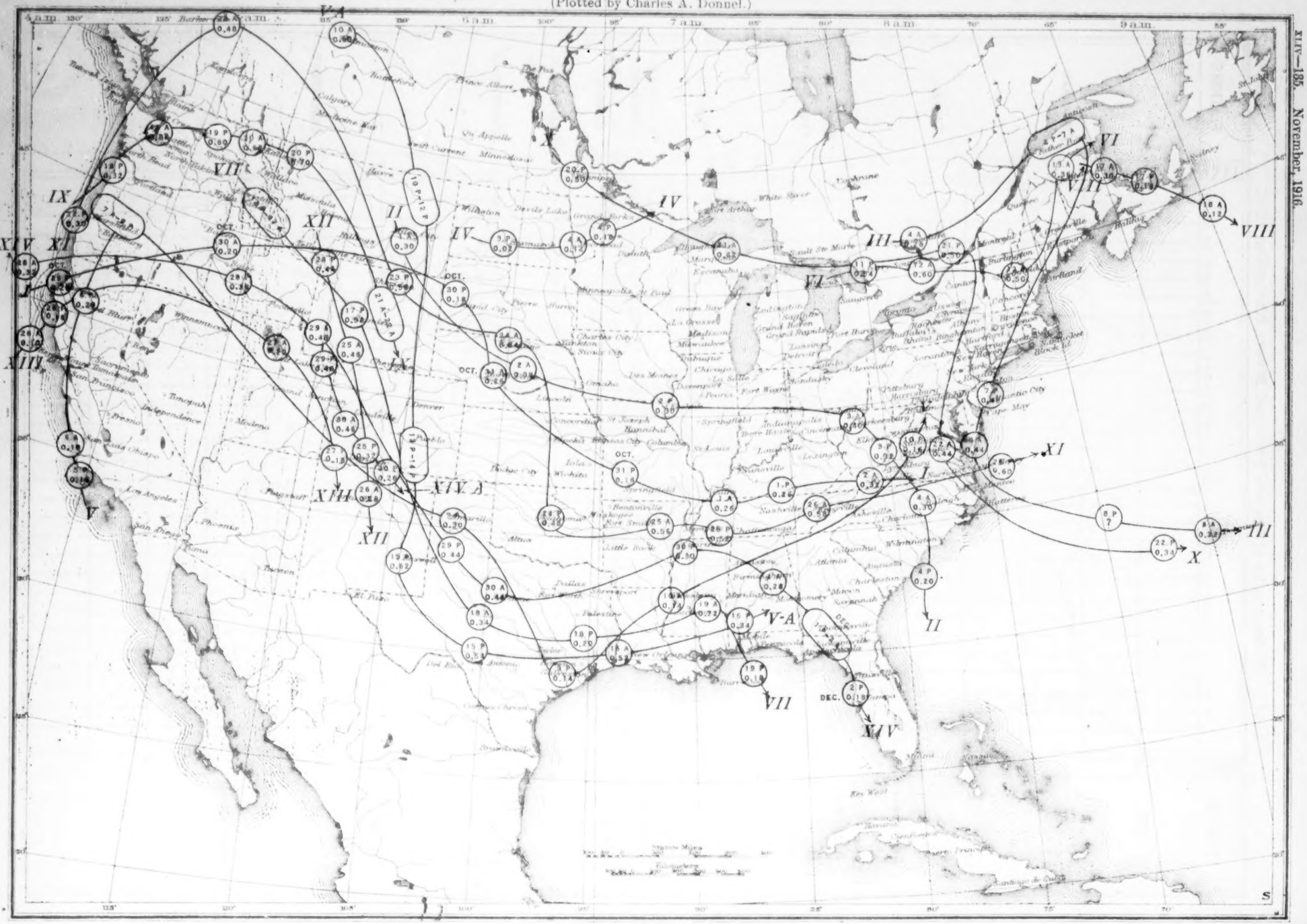


Chart III. Tracks of Centers of Low Areas, November, 1916.

(Plotted by Charles A. Donnel.)

Chart III. Tracks of Centers of Low Areas, November, 1916.

(Plotted by Charles A. Donnel.)

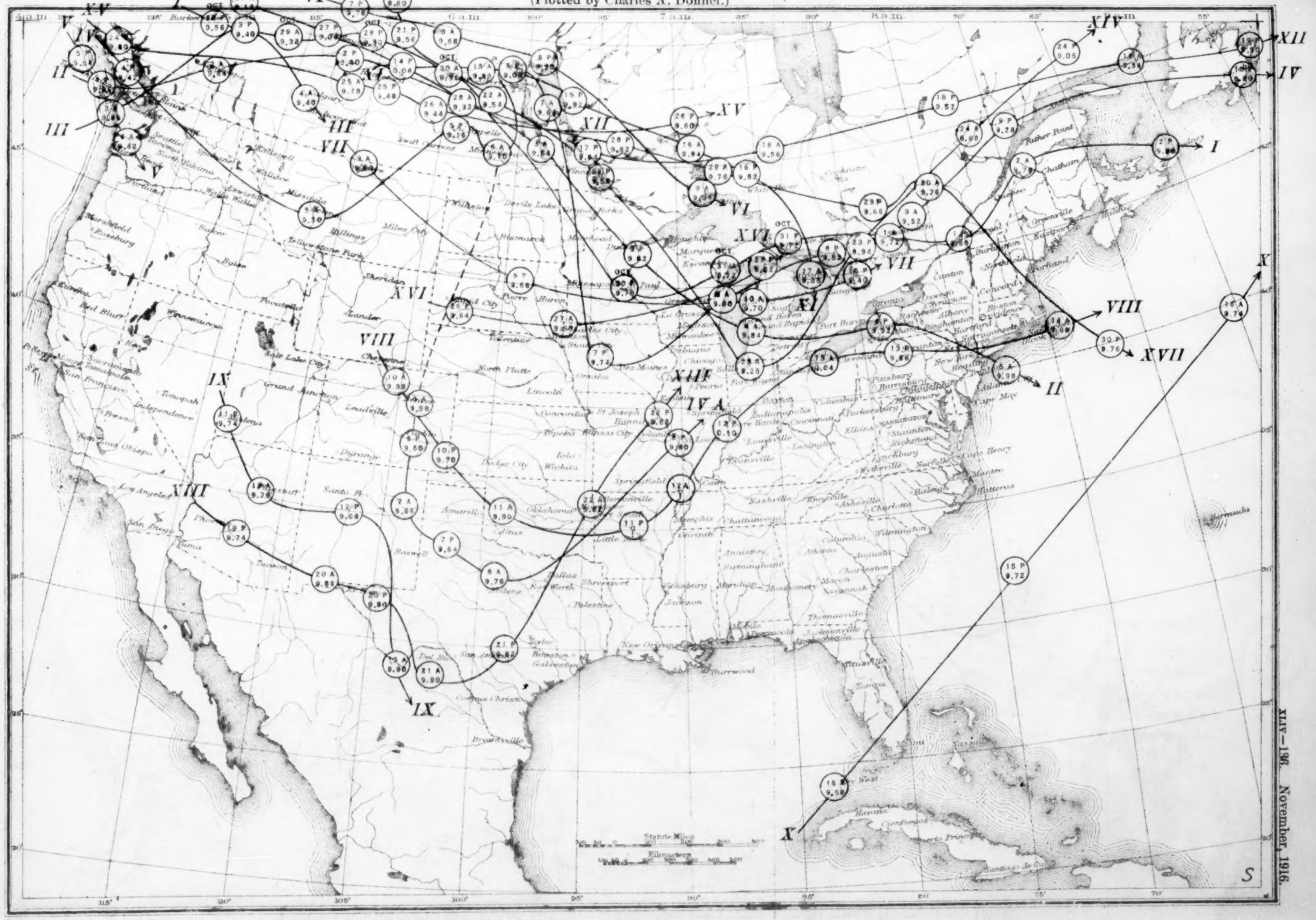


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, November, 1916.

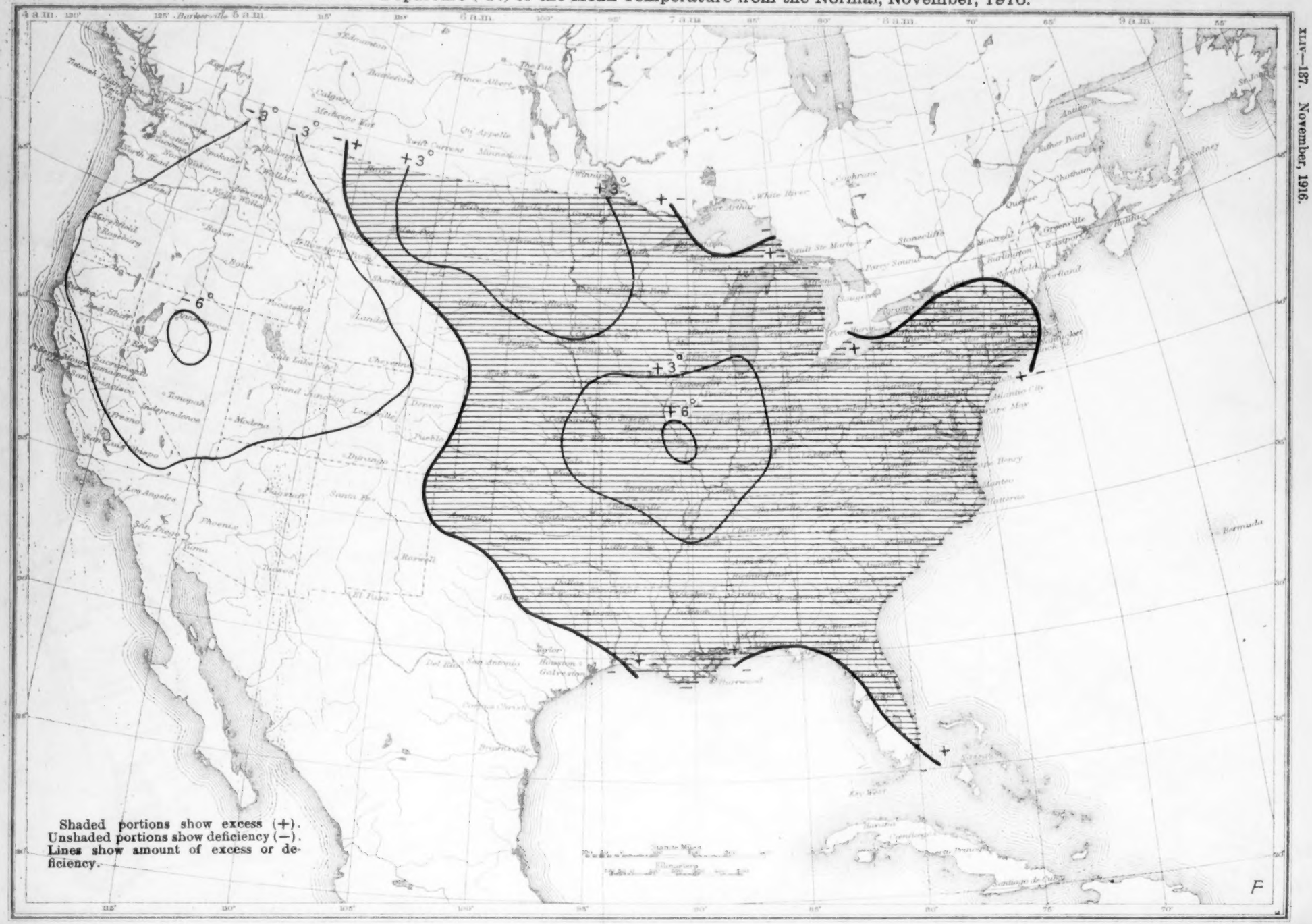


Chart V. Total Precipitation, November, 1916

Chart V. Total Precipitation, November, 1916.

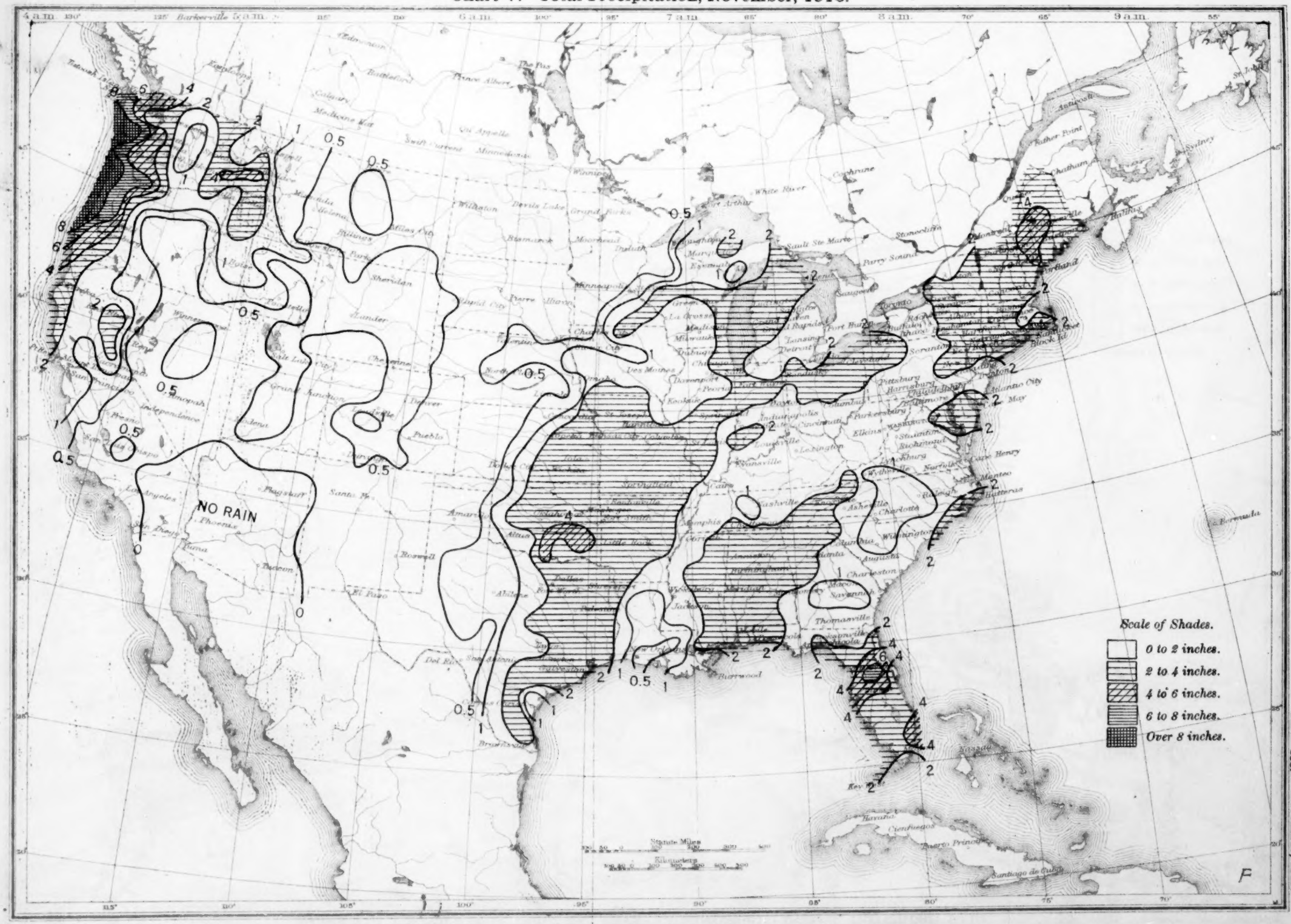


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, November, 1916.

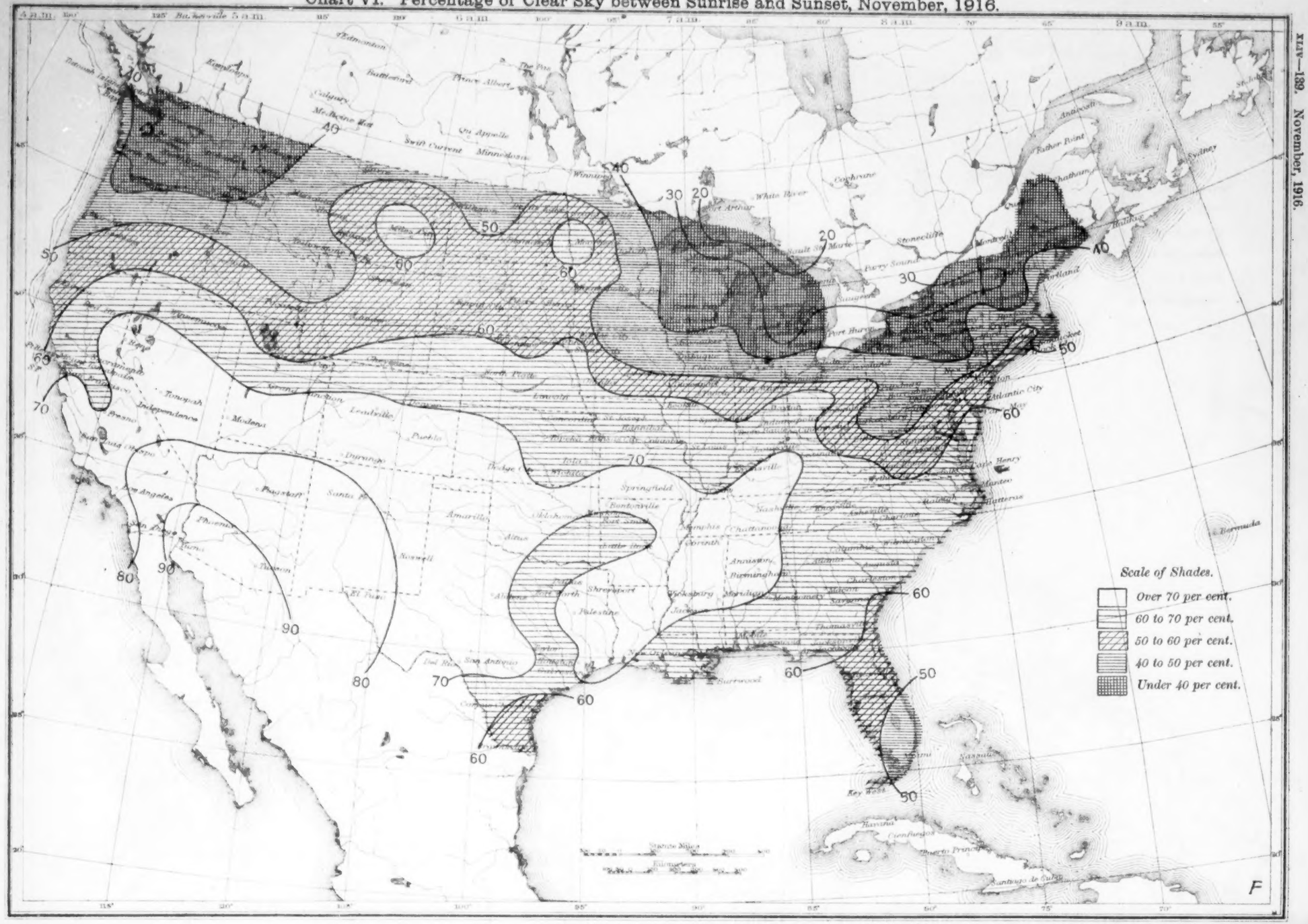


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, November, 1916.

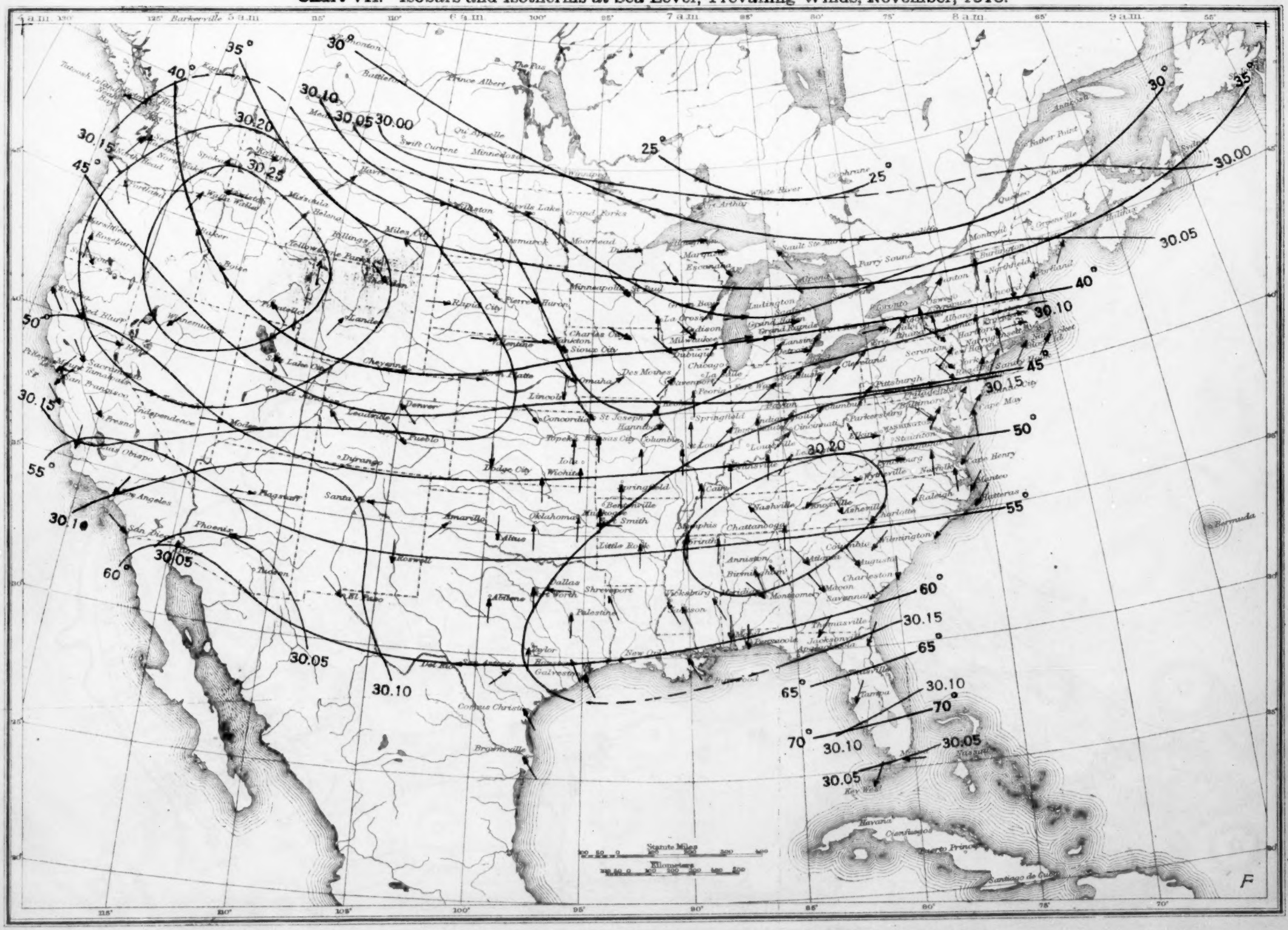


Chart VIII. Total Snowfall, Inches, November, 1916.

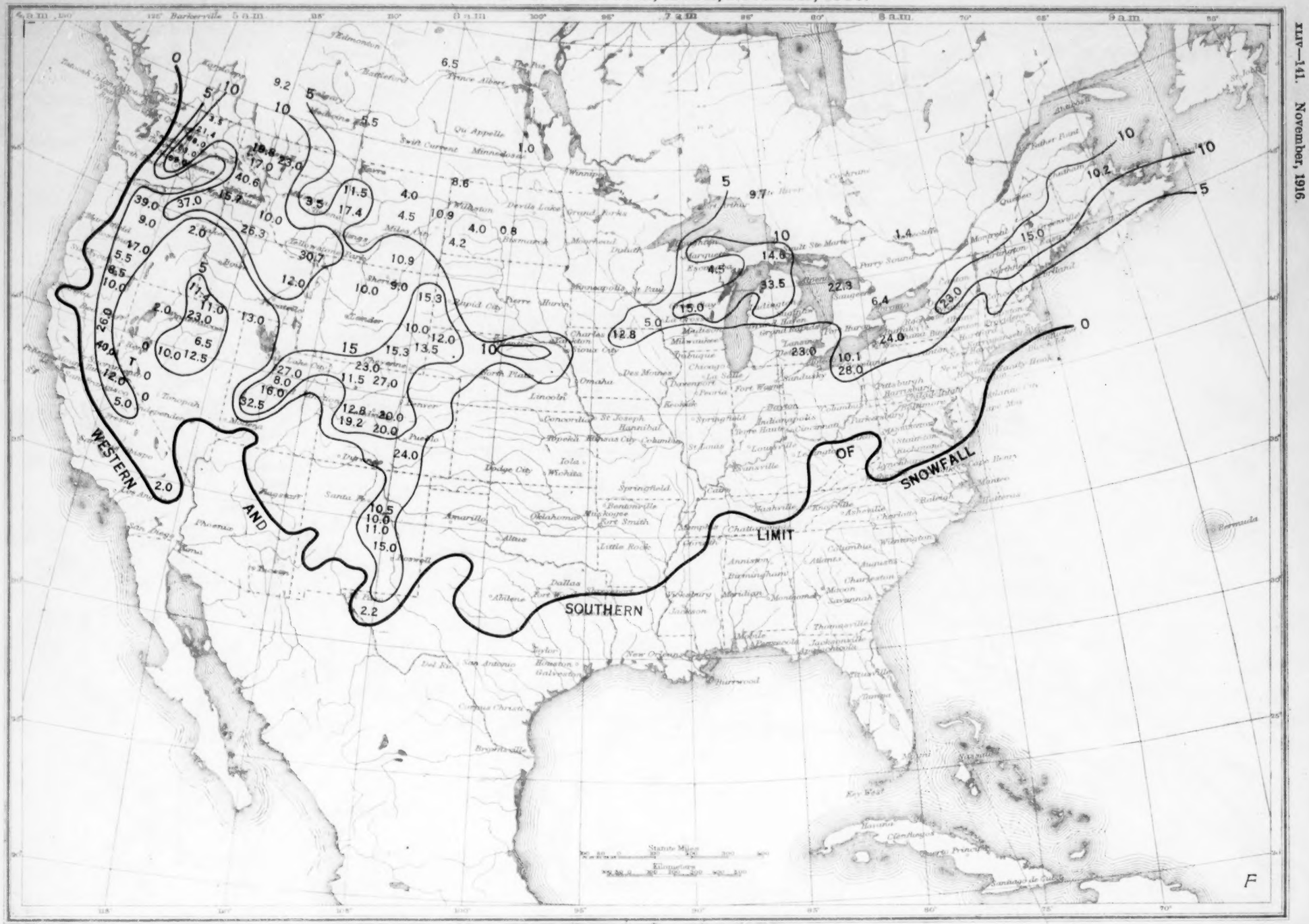
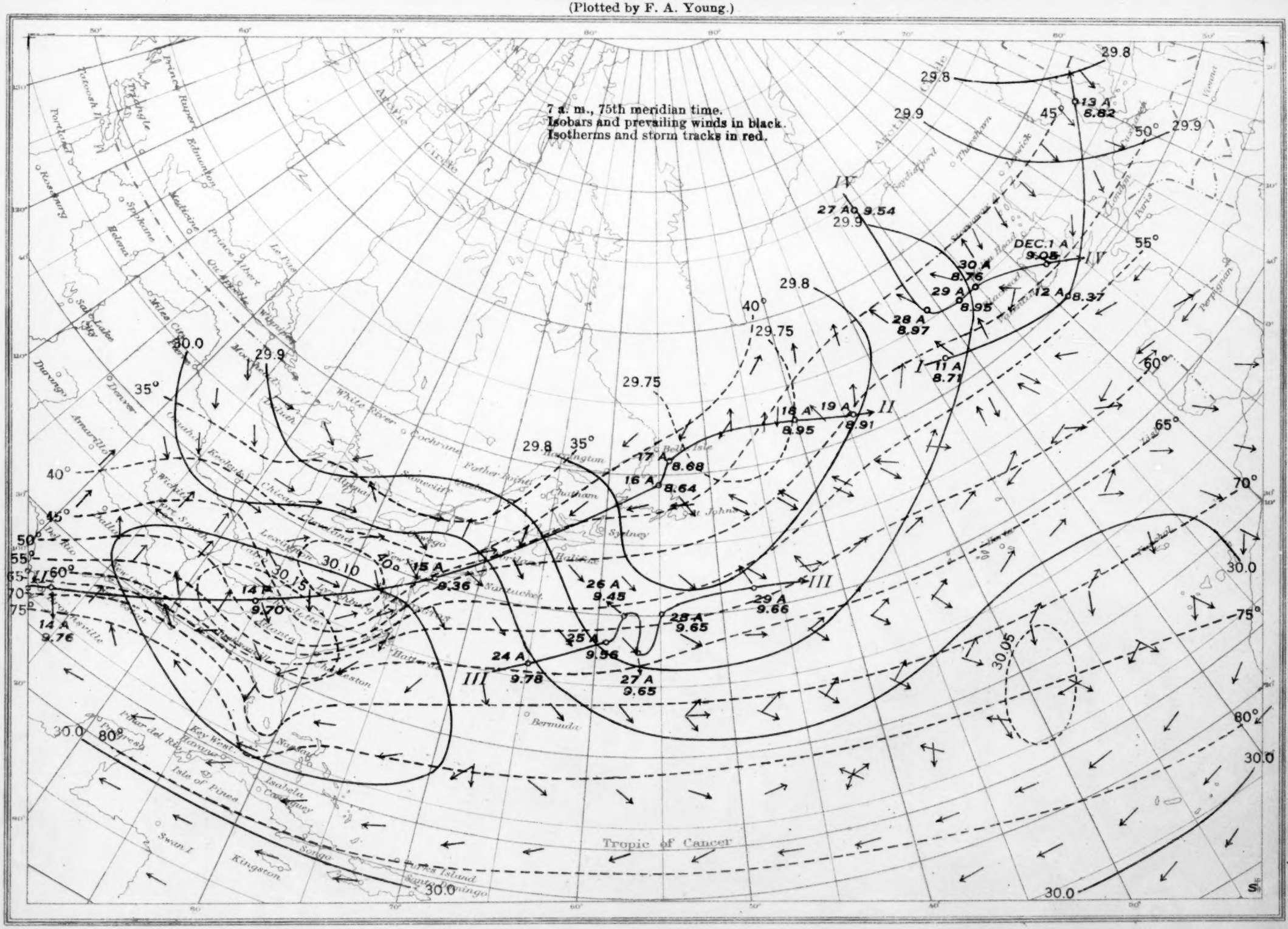


Chart IX. Means of Meteorological Data for North Atlantic Ocean, November, 1915.

(Plotted by F. A. Young.)

Chart IX. Means of Meteorological Data for North Atlantic Ocean, November, 1915.

(Plotted by F. A. Young.)